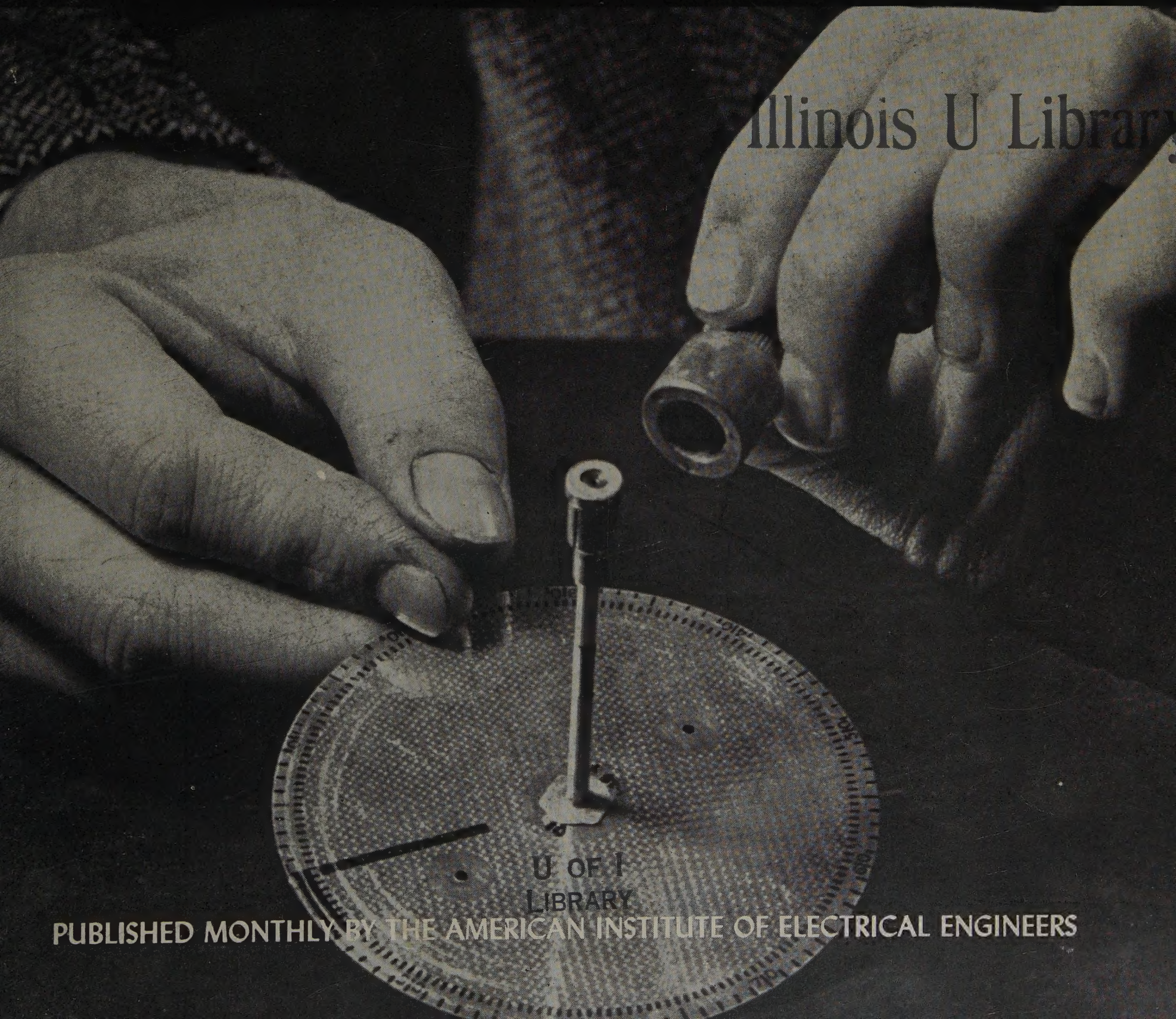
ELECTRICAL ENGINEERING

JULY 1948



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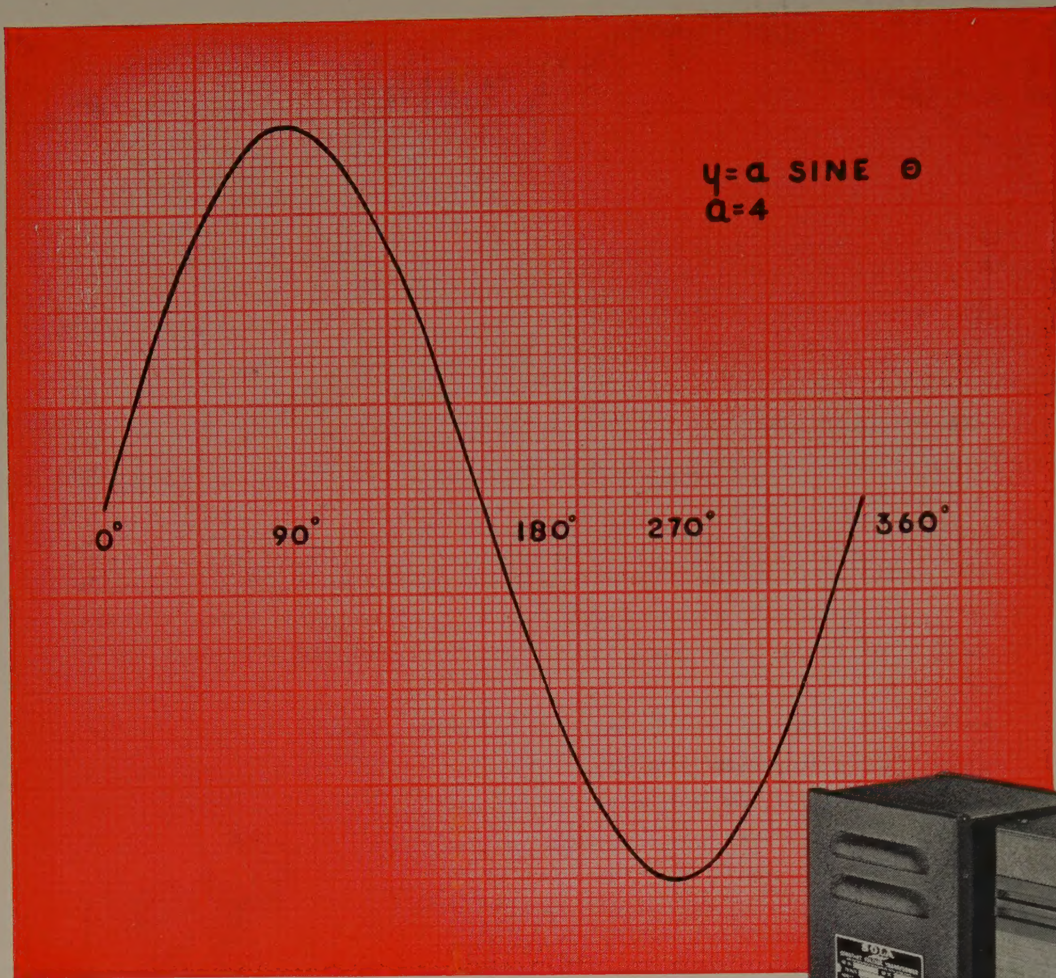

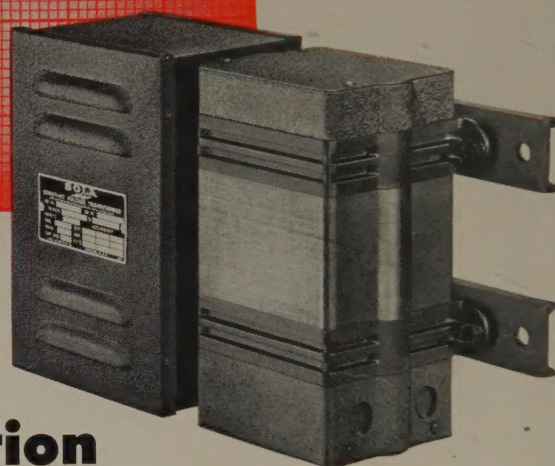

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JULY

1948

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HIGHLIGHTS........

Summer Meeting. As this issue is being distributed the AIEE summer general meeting is in progress in Mexico, Federal District, Mexico. A report on this meeting will appear in forthcoming issues of *ELECTRICAL ENGINEERING.*

AIEE PROCEEDINGS. The second order form for 1948 AIEE *PROCEEDINGS* sections is scheduled to appear in next month's issue. Members interested in obtaining already published sections are referred to the AIEE *PROCEEDINGS* box for necessary information (*page 708*).

Rubber Conference Papers. Authors' digests of the seven papers presented at the AIEE conference on electrical engineering problems in the rubber and plastics industries, which was held in Akron, Ohio, April 20, 1948, appear in this issue (*pages 704–06*).

New Haven Meeting Papers. Brief authors' digests of the conference papers presented at the North Eastern District meeting which was held in New Haven, Conn., April 28–30, 1948, appear in this issue (*pages 695–703*).

Digests. More one-page digests of technical program papers which replaced the formerly published abstracts (*EE, Apr '48, p 378*) appear in this issue. These include several North Eastern District meeting digests as well as summer meeting digests of technical program papers (*pages 625, 626, 637, 645, 646, 655, 656, 661, 662, 694*).

Conservation. "It is imperative that we appreciate that only a few hundred pounds of a mineral can decide the future of a nation," and so it is imperative that the United States embark upon a program of conservation of its natural resources, a number of which are being depleted at a very rapid rate. Such a program advocating conservation recently was endorsed by The Connecticut Technical Council (*pages 718–19; pages 623–4*).

Steinmetz Memorial Lecture. Philip Sporn, president of the American Gas and Electric Service Corporation, delivered this year's Steinmetz Memorial lecture, 21st in a series of annual lectures presented as a "living memorial" to Charles G. Steinmetz, and to honor the speaker selected to give the lecture (*pages 630–6*).

Trends in Electronics. "The field of electronics has emerged in the postwar world as the most active branch of electrical science." It is made up of three areas of activity—entertainment and education, communications, and industrial applications—and trends in each of these divisions since the war are considered in this article by the editor of the magazine *Electronics* (*pages 647–53*).

Modern Telegraph Switching. "Business has taken communications from the cellar and put it in the front office." The modern reperforator switching system can do just that! Intercity intracompany communication can be handled more quickly, efficiently, and reliably with the use of carefully engineered switching centers (*pages 638–44*).

Last Call for 1948 TRANSACTIONS. Advance orders for the 1948 bound volume of the AIEE *TRANSACTIONS* must be received by August 15, 1948, to assure delivery early in 1949. Members' price is $5 plus $1 for foreign postage. The nonmembers' price is $12 plus $1 for foreign postage. Discounts from this price may be allowed to college and public reference libraries (25 per cent) and to publishers and subscription agencies (15 per cent). Subscriptions from nonmembers are payable in advance. A convenient coupon is given below.

Transformer Standards Compared. An examination of the various standards governing manufacture and use of transformers shows that the International Electrotechnical Commission specifications are not being followed in many countries. Although varied conditions demand varied practices, there should be an international standard and factors by which other standards could be compared (*pages 663–7*).

Atomic Pile Theory. Nuclear reactors are described and critical factors analyzed. Though advanced mathematics must be used, a nonmathematical section is included. This is the eighth of a series of articles developed by the AIEE nucleonics committee. At the conclusion of the series, a consolidated pamphlet of reprints including the entire series will be available to interested readers (*pages 685–93*).

Models of Equations. By setting up electric circuit models of partial differential equations, the solution of many problems in fields other than electrical engineering may be transferred to the a-c calculating board. Much of this work never has been reported previously to the Institute membership (*pages 672–84*).

Magnetic Bearings. A magnetic field instead of the conventional jewel bearings is used to support the rotating element in a new watt-hour meter. Maintenance is reduced because this method of support is nonwearing and requires no lubrication (*pages 627–9*).

Electric Power Source. The last of a series of articles reviewing methods of producing electric power discusses general considerations in thermoelectric generator designs. The entire series will be published in pamphlet form (*pages 657–60*).

Electrostatic Generators. In spite of relatively high voltages and currents, all of the magnetic accelerators suffer from disadvantages which preclude any extensive use of these machines in the making of certain precision measurements. The electrostatic generator, however, has such unusual aptitudes for experiments of this type that it has been termed "the work horse of nuclear physics" (*pages 668–71*).

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Conservation of Natural Resources

T. J. RUSSELL
ASSOCIATE AIEE

The question of conservation is an especially important one in the United States today when we find ourselves faced with the possibility of a number of our natural resources giving out, and it is the engineer, whose responsibility it is to convert these materials into forms suitable for use by man, who has a special interest in the problem. This article stresses the urgency of the need for a program of conservation of our natural resources such as recently was endorsed by The Connecticut Technical Council, of which the author is chairman.

AS ENGINEERS, we find that one of the most important of our responsibilities is to put the world's resources to work for mankind and thereby contribute to the building of his civilization. Engineers convert nature's materials by research, design, construction, and production into man's necessities, comfort, and luxury items. It is obligatory upon us to get the very most out of every ounce of material taken from nature's storehouses. Hence, we are vitally interested in conservation of our natural resources.

As far back as 1869 George Perkins Marsh wrote, "Man has too long forgotten that the earth was given to him for use and enjoyment alone, and not for impairment; still less for profligate waste."

While a material is plentiful we humans seem to give very little thought to the possibility of the supply running out. However, today we are face to face with the possibility of quite a number of nature's resources giving out.

We long since have learned that if we are going to pull up a thistle by the side of the road, we should plant a violet. Therefore, any discussion of the importance of conservation of natural resources should include some suggestions along the lines of how this may be accomplished.

WHAT CONSERVATION MEANS

The advocation of conservation does not mean to curb or forbid the use of minerals, petroleum, chemicals, and forests, but it absolutely does mean seeing to it they are not wasted. This can be accomplished by better co-operation between privately owned companies and government of mines, oil fields, forests, as well as the substitution of materials that are plentiful, where possible, instead of the rare and scarce. It does not mean, however, the arbitrary application of restrictions by government or industry.

Beyond all reasonable doubt the nuclear physicists eventually will harness power that successfully will supplant our natural gas, petroleum, and other products. However, conservation should be the better part of valor in the meantime.

The earth, as a whole, consists of metal but, unfortunately, most of it is in the interior and therefore inaccessible. The core of our planet evidently consists mainly of iron and nickel. The crust consists mainly of a layer of silicates and sulphides and these contain relatively very little metal.

Engineers enter into the metal resource picture very prominently. To get metals out of the earth we employ the mining engineer; to refine and alloy them the metallurgist comes into the picture; and to protect them against heat, corrosion, and wear we call upon the chemical engineer as well as the metallurgist.

Electroplating is playing an important part: copper plating for drawing operations; silver plating on bearings to prevent seizure; chromium plating for salvage work and wear resistance.

Scrap drives should be practiced in peace as well as in war time. Furnaces are down now that would be running if scrap iron were not so scarce, and so the people should be made metal-saving conscious.

Another important part of waste elimination is the employment of the most efficient refining methods.

If we in the United States are to continue to be a republic, and if we are to preserve those resources on which our democracy rests, it is necessary that a large number of people do something about it. We the people must do it or government will do it through agencies.

The principal basis of national wealth and power is soil, metal ores, coal, oil, natural vegetation, animals, water, and climate. All these are results of biologic and geologic history of a land.

The great Planner has been working through nature millions of years to fill the storehouses.

THE ROLE OF MAN

We must not overlook man in our considerations. However, instead of being a producer in this program, he is all too often the waster and dissipator of the rare, valuable, and even the common and plentiful of nature's products found on our planet.

We find men who seem to have something in their makeup that causes them to be the destroyers of everything that our culture needs to thrive on. On the other hand, there are those who give their all to the preservation of the elements that are the requisites of our civilization. Some of these men believe that the only solution is a program of national planning (by government). The author hopes and believes it can be done in the free enterprise way: By national planning on the part of industry and business in co-operation with government (but not government control) through research and elimination of waste, waging war on erosion and

Essentially full text of an address presented at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948.

T. J. Russell, application engineer, Westinghouse Electric Corporation, Bridgeport, Conn., is chairman of The Connecticut Technical Council, Inc., New Haven, Conn.

corrosion, co-operation with military branches in building up stock piles of vital materials. As previously stated, we do not want to curb industry, but it has been said that greed and the profit motive make such a program impossible. Such a statement is highly debatable. The best remedy seems to be to make the American people mindful that our national life's blood is our resources and that they must be wisely and efficiently used, a remedy which is recommended in spite of the somewhat optimistic feeling of the Department of the Interior.

It is a long way back to Colonel Drake at Titusville in 1869 but unless we are careful we will be back even further, we will have little or no oil or gasoline.

When reserves are tapped for the Army, Navy, and Air Corps, we must be sure there are no individuals passing out leases on oil fields.

The engineer is, or at least should be, as interested in soil and forest conservation as he is in conservation of our metals, because so many of our necessities, other than food, come from agriculture and forest products.

Nitrogen, potassium, phosphorus are very vital to the continuity of plant, crop, and forest life. Potassium is very plentiful at present. Nitrogen can be obtained from the air. However, phosphorus must be mined and the deposits are not unlimited. Within the national boundaries of the United States there is approximately 30 per cent of the world's known deposits of phosphorus. Lacking this vital material all plant and animal life dies.

As far as agriculture is concerned the Department of Agriculture is doing a fine job in educating farmers to use "strip planting," "cover crops," and "shelter belts."

The larger lumber companies are practicing the cutting of timber with greater care and following this by replanting. Our land escaped bombs and high explosive shells during both the first and second World Wars, but it has not escaped erosion and dust storms brought about by careless, ignorant cultivation and timber cutting. In spite of optimism of many of the poorly informed, the pressure of war cannot by magic work the low grade ores without having the necessary methods planned and worked out in advance.

SUGGESTED PROGRAM

Each of us can do something about this conservation problem by writing our congressmen and senators urging them to support "stock pile programs for our military forces." The stock piles of rubber, tin, lead, zinc, pig iron, and numerous chemicals also should be on hand to carry us over any stoppage of world trade.

The author has called upon the President of The United States in the name of The Connecticut Technical Council to give heed to the Herter Report, and suggested that all of the relief to foreign nations be on a strictly business basis, and that the payment be required in the form of raw materials. Not only will a program of this type supplement our dwindling resources, but it will contribute to the recipients of our assistance by maintaining their self-respect and will contribute further to our economic stability. It is possible to print or mint money in rather a short time, but it has taken nature centuries to build up the storehouse of vital materials that we waste in a few years.

Except for, perhaps, deposits on the continental shelves under the oceans, our last great finds of gold, silver, copper, oil, and coal have been made—we have reached our peak in gold production and the best anthracite is gone, as well as most of our pig iron resources. There is a great store of magnesium in the sea waters of our planet, but this metal cannot alone save us. Those of us who are lulled into semi-consciousness by some of our fellows who so glibly write and talk of the limitlessness of science, will do well to waken themselves to the fact that we are not freed from the forces of gravity that bind us to earth. Perhaps we may find a way to get power from a central source that will be transmitted through the ether to run our plants, transportation facilities, automobiles; heat, cool, and air condition our homes; and melt snow and ice on our streets and highways. However, it will be years before this is accomplished. In the meantime, we must consider and reckon with one of our strongest and most common enemies, the numerous forms of corrosion which include uniform attack, intergranular, pitting, erosion corrosion, galvanic or 2-metal corrosion, and stress corrosion. In our fight against erosion, we call in the agriculturist. In the battle against corrosion, one of the greatest devourers of our vital metals, we call on our army of metallurgists. Results thus far show they are advancing on all fronts and their contribution toward conservation is noteworthy through use of protective films, paints, and other organic coatings or vitreous enamels.

A SUMMARY

To summarize, it is imperative we appreciate that only a few hundred pounds of a mineral can decide the future of a nation.

We seem to have a good supply of coal, salt, potash, sulphur, iron ore, and phosphate rock. Such minerals as tin, nickel, quartz crystals, and platinum are scarce, as are tungsten, manganese, and mercury, and geological surveys show very little possibility of any new discoveries.

Our copper and zinc situation is a sad one.

Consequently, we must push geological research as well as efficient methods in mining and refining of our minerals.

We must educate the public to save every ounce of metal possible.

We must guard our forests and soil.

We must make sure that all our dealings with foreign governments are on a strictly business basis.

And we must lend our strength to preserve our national strength by doing everything in our power as engineers to preserve our resources. We must include in our "jobs ahead" the most urgent and important one of putting our support back of any movement or legislation that has anything to do with strengthening our nation by conserving our natural resources.

It is time we ceased being frustrated and chose the correct path; a humanitarian businesslike conduct of our daily production, business, and dealings with foreign nations seeking our assistance, instead of wastefulness and giving until our whole economic standing is undermined.

It is time that we changed our day dreaming into active thinking and lent our aid and support to conservation of our vital life, our natural resources.

Frequency Converter Performance Calculations

FREDERICK R. LATZKO
MEMBER AIEE

IN ITS GENERAL construction the induction-type frequency converter is identical with a standard slip ring motor. Connecting its primary to a line of frequency f_1 sets up an air gap flux revolving at synchronous speed n_s in respect to the primary winding, inducing in the secondary a voltage of a frequency f_2 in direct proportion to the difference between shaft speed n and n_s. Introducing the slip $\pm S = \pm f_2/f_1$ and the number of poles P, two convenient formulas for the selection of converters are obtained:

$$n = [1 \mp S] n_s \tag{1}$$

and

$$f_1 \mp f_2 = Pn/120 \tag{2}$$

Equation 2 is plotted in Figure 1 for 2 to 20 poles and for shaft speeds up to 4,800 rpm.

Electric power (P_{1w}, P_{2w}) may be absorbed or delivered through the primary or secondary terminals; mechanical power P_m through the shaft. For an ideal converter without losses and magnetizing current the relationship shown as a graph in Figure 2 holds true:

$$P_m/P_{2w} = 1 \mp f_1/f_2 \tag{3}$$

The minus sign in the foregoing formulas applies for operation at positive slip.

The inherent difference in performance operating at positive or negative slip becomes particularly apparent in the special case $f_2 = f_1$. At standstill ($s = +1$) the mechanical power is zero; running at double synchronous speed ($s = -1$) twice the secondary output must be delivered mechanically through the shaft.

The frequency converter can be considered as a slip ring motor, compelled to operate at a fixed slip with an impedance in series with its secondary winding. It is convenient to figure the load constants for a given apparent power P_2, power factor $\cos\theta_2$, number of phases m_2 and phase voltage E_2 in terms of f_2 from:

$$Z_L = m_2 E_2 / P_2 \tag{4}$$

$$R_L = Z_L \cos\theta_2 \tag{5}$$

$$X_L = Z_L \sin\theta_2 \tag{6}$$

Figure 3 shows the equivalent circuit in which all constants must be expressed in terms of f_1 and reduced to the primary winding. For this purpose all secondary constants are multiplied by an impedance reduction coefficient a_z (square of the effective turn ratio). The resistances must be divided by $\pm s$ or multiplied by $a_F = \pm f_1/f_2$. The load reactance must be multiplied by $|a_F|$ to reduce it to f_1. It should be understood that the load constants are fixed by specifications, while the machine constants must be chosen by some trial design in a manner to give the specified load values for E_2 and P_2. The determination of the accurate shaft power requires the calculation of all losses in the frequency changer, primary and secondary I^2R losses, primary and secondary core losses, windage, and friction. The algebraic sum of the three powers (shaft, primary, secondary) and the internal losses always must be zero.

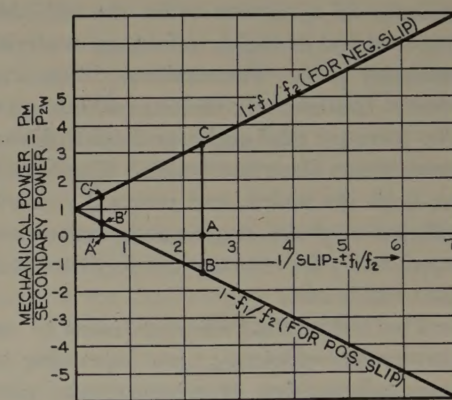


Figure 2. Curve showing the ratio of mechanical power to secondary power

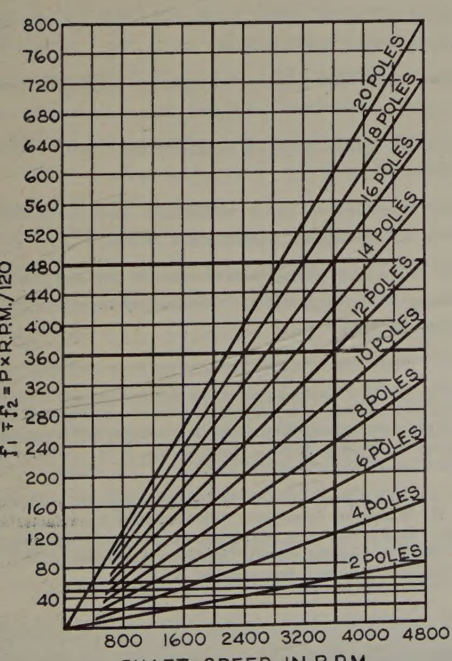


Figure 1. Chart for selecting frequency converters

Digest of paper **48-161,** "Performance Calculation of Induction-Type Frequency Converters," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Frederick R. Latzko is with the Electric Specialty Company, Stamford, Conn.

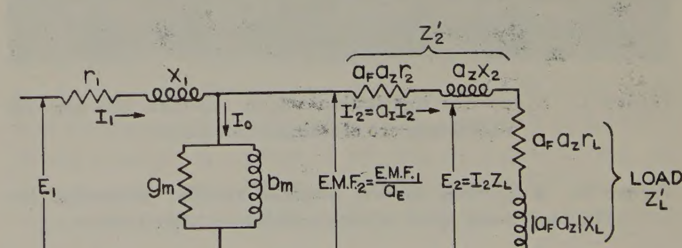


Figure 3. Equivalent circuit of the frequency converter

Mercury-Arc Power Converters in North America

AN AIEE COMMITTEE REPORT

USE OF METAL-TANK rectifiers for converting alternating current to direct current has increased rapidly in the United States and Canada since 1925. Initial applications were in electric railway service and the rectifiers were of the multianode design. Direct potentials were at levels of 600, 1,500 and 3,000 volts, and capacities were of the order 1,000 to 3,000 kw. Development of single-anode mercury-arc rectifiers received a decided impetus in 1933 with the introduction of the ignitron. In the ignitron a new cathode-spot is established for each conducting cycle by passage of a current pulse through the ignitor—a small tapered rod of highly refractory material immersed in the mercury pool. The excitron differs from the ignitron in that a continuously excited cathode-spot is maintained on the mercury pool and a grid controls the starting of anode conduction electrostatically. Single anode tubes are made in both the sealed and pumped construction. Improved efficiency of the single-anode units extended the field of application for mercury-arc rectifiers to the industrial 250–600-volt levels.

The outstanding characteristics of mercury-arc power converters—efficiency, low operating and maintenance costs, elimination of synchronizing problems, high fault capacity, lack of noise, low weight, and no rotating parts requiring special foundations—have resulted in the installation of more than 5,000,000 kw of capacity up to the beginning of 1948. By far the largest installed capacity is in the electrochemical field. Nearly 3,000,000 kw are installed for the formation of aluminum alone. Figure 1 shows a rectifier installation for the supply of two 650-volt 60,000-ampere aluminum pot-lines. Mining represents an important and growing field, particularly for the sealed rectifiers. Compact, mobile, low-height rectifiers for this service permit the rectifier to be moved easily as the working area progresses and thereby to maintain adequate direct voltage at the working face. Figure 2 shows a 275-volt 300-kw mine type rectifier using sealed tubes. Railway service and the introduction of trackless trolleys represent other fields.

Among the many interesting and new applications are the electronic frequency converters that have been installed at the Gary (Gary, Ind.) and Edgar Thomson plants (Pittsburgh, Pa.) of the Carnegie-Illinois Steel Corporation to provide nonsynchronous interchange of power between their 25- and 60-cycle systems. The Gary frequency-changer capacity, initially of 6,667 kw and using multianode pumped rectifiers, will be increased shortly to 8,000 kw capacity with the installation of pumped single-anode excitrons; and a second unit added. The 20,000-kw Edgar Thomson frequency changer consists of two 10,000-kw units and uses sealed ignitron tubes of the pentode type. Frequency changers for higher frequencies (60 to 1,000 cycles) using mercury-arc rectifiers have been developed for induction heating and the melting of metals in brass and steel foundries.

The problem of possible interference in communication lines exposed to harmonics generated by the rectifier action is discussed technically and the methods of control indicated.

Conclusions reached in the report indicate that

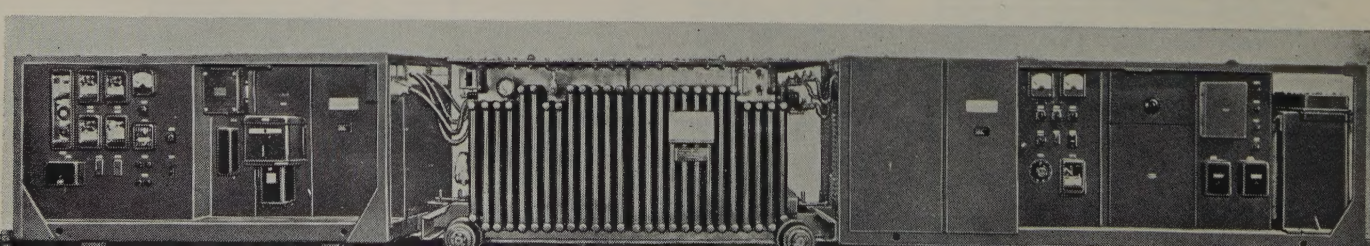
1. Single-anode pumped tubes of 1,000 amperes capacity are as large as are needed for present applications.
2. Sealed tubes of more than 400 amperes capacity probably will be developed.
3. There will be increasing application of mercury-arc rectifiers for variable-speed motor drives.
4. Higher-power radio transmitters and induction and dielectric heating equipment are also promising application fields.
5. Future application of mercury-arc power converters for long-distance d-c power transmission depends on additional development work and economic considerations.

Figure 1. A rectifier installation which supplies two 650-volt 60,000-ampere aluminum pot-lines

Figure 2. A 275-volt 300-kw portable rectifier substation for underground mine service which uses sealed tubes

Digest of paper 48-188, "Mercury-Arc Power Converters in North America," recommended by the AIEE electronics and electronic power converter committees and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

This paper was prepared by a working group of the AIEE electronic power converter committee which included **H. Winograd** (*chairman*), Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; **C. R. Marcum**, Westinghouse Electric Corporation, East Pittsburgh, Pa.; **L. W. Morton**, General Electric Company, Schenectady, N. Y.; and **H. C. Steiner**, General Electric Company, Schenectady, N. Y.



A New Watt-hour Meter

I. F. KINNARD
FELLOW AIEE

A most important link in the chain of electric energy supply always has been the watt-hour meter. Meters have been developed and improved during more than 50 years; now new material has made possible a design with magnetic suspension of the moving element.

MEASUREMENT of electric energy always has been a vital factor in the development of the electrical industry. At the outset it was realized that widespread growth would involve simple and equitable means of measurement. Much of the early work of Edison was directed toward a means of replacing the first practice of measurement based on the number of electric lamps. In 1881 he introduced the chemical meter, which was used to measure ampere-hours in first d-c systems of distribution. In 1889 production was started on the first commercial watt-hour meter in the form of the Thomson recording wattmeter, which was applicable to alternating or direct current. In 1894 the Shallenberger induction-type a-c watt-hour meter was introduced. This principle has proved so well suited to the need that it has been used continuously since then. Present-day watt-hour meters and the new meter described herein retain the fundamental induction principle. Progress in the art of metering has seen several superseding designs, with progressive development and improvements occurring during one-half century.

The present-day watt-hour meter is a high-quality precision device. There are few, if any, commodities on the market that are measured more accurately than electric energy. Not only do meters have a very wide load range from a starting load of 1/3 of one per cent of rating to a maximum load of 400 per cent of rating, but they are temperature compensated for the extreme ranges in temperature found out-of-doors in northern and southern latitudes. Stability and life have been improved to the point that it is common practice for electrical utilities to check meters only once every eight years. However, it has been found possible to develop a new single-phase watt-hour meter with new and outstanding features in all components.

The major objective in this development has been to reduce maintenance. This has been accomplished through the use of a magnetically supported moving element and an over-all co-ordinated design wherein bearing maintenance has been eliminated and high accuracy and long life are realized. In keeping with the long bearing life many advances in improved insulation and better corrosion resistance have been incorporated to give a long life without maintenance. Other advantages include improved performance and appearance, a reduction in size of 18 per cent, and a weight reduction of 30 per cent.

MAGNETIC SUSPENSION OF THE MOVING ELEMENT

The magnetic suspension of the moving element is the central feature of the new meter. A small amount of magnetic material supports all the weight of the disk and shaft and eliminates the need for jewel bearings, which have been the main cause for meter maintenance. Previous work with jewel bearings using pivots or balls and various materials and lubricants has not resulted in a complete solution.

The construction of the magnetic suspension is shown in Figure 1. Two cylindrical permanent magnets of the high-coercive and machinable material cunico are placed one within the other, the outer magnet being fixed to the meter frame and the inner magnet attached to the upper end of the disk shaft. The concentric magnets are magnetized axially with opposite polarities. The resulting field supports the rotating moving system at a definite and small downward displacement.

To keep the moving system in line, stainless-steel guide pins are provided at the top and bottom. Graphite guide bushings at both ends of the shaft run on these guide pins without lubrication. The only possible cause of mechanical friction and wear in this system is the presence of side-thrust forces, and the design has been made so that these are inherently very low. This construction replaces the conventional bearing where the entire weight of the moving system and most of the side-thrust forces are supported in the jeweled lower bearing.

In the conventional jeweled bearing stress due to the weight of the disk is of the order of 200,000 pounds per square inch. In the magnetically suspended moving element the bearing stress due to the weight of the disk is completely eliminated. Moreover, the torque-to-weight ratio, which has long been accepted as being in the order of 3 or 4 to 1, has been increased to infinity. This comparison in both cases ignores the secondary effects of side thrust.

Side-Thrust Forces. With all the weight of the moving system supported magnetically, the only forces significant to wear are side-thrust forces which arise primarily from the action of the electromagnet and the damping magnet on the meter disk. In co-ordination with the use of the magnetic suspension the meter structure has been arranged to keep the side-thrust forces low in value. In the conventional meter the electromagnet is mounted back of the frame and disk shaft, and the damping magnet is located at the front of the meter. Figure 2*B* shows a top schematic view of the meter disk with the electromagnet on one side of the shaft and the damping magnet poles on the other side of the shaft. When a torque is created in the disk by a power load, the driving torque is equivalent to a side thrust at the location of the electromagnet. Motion of the disk causes a correspond-

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ing side thrust at the damping-magnet position. The total side thrust on the disk bearing is equal to the sum of these forces.

Completely to eliminate side thrust would require having the electromagnet and the damping magnets in the same location. In the new meter the large reduction in the side thrust has been achieved by locating the damping magnets closer to the electromagnet than has been heretofore possible. As shown in Figure 2*A*, it has been found possible to locate the permanent-magnet poles nearer the electromagnet so that they create practically no net side thrust and the only significant side thrust present is that due to the electromagnet. This pressure is in the order of 100 pounds per square inch at maximum load, which is conservative for the material involved and of a very different magnitude from the pressures found in conventional jewel bearings.

A second possible cause of side thrust in a moving system supported by magnetic suspension may arise in the magnetic suspension itself. This happens if the inner magnet is eccentric with respect to the outer magnet and increases with increased displacement. This was one of the causes of the failure of an early attempt to apply a magnetic suspension to a moving system. In this case the flux crowding due to the use of soft-iron pole pieces on the stator and rotor caused considerable side thrust with the displacements encountered in manufacture and service. The availability of cunico has made possible the present design without soft iron and with only small stator and rotor magnets to give the necessary lifting force. As a consequence, and because of the proportions used and precision manufacturing, the side thrust due to eccentricity is so small that it may be neglected.

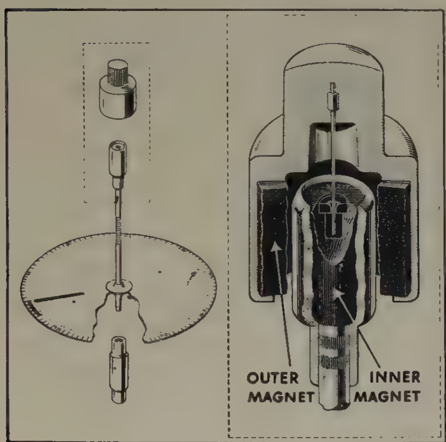
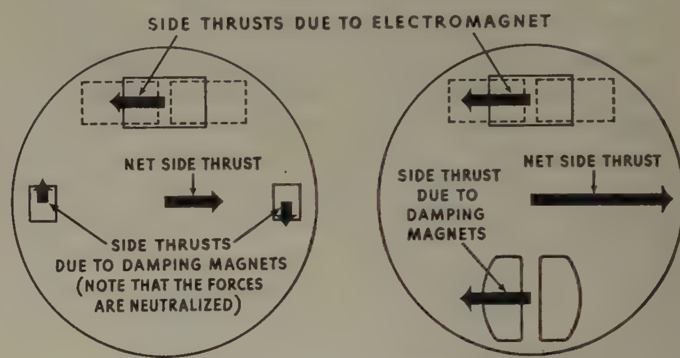


Figure 1. Diagram of magnetic suspension



A—Type I-50 *B—Conventional meter*

Figure 2. Comparison of side thrusts

Magnetic-Suspension Life Tests. Development of the magnetic suspension was well under way before the war. It was applied to 194 older type meters and started on life test in October 1941. Since then these meters have been operating at varying loads on a daily cycle that gives about ten times normal registration, so that in nearly seven years the registration per meter has totaled normal registration of 65 years or about 80,000,000 revolutions. This test has shown excellent stability of the magnetic suspension. At the same time it has served as a proving ground for the proper guide-bushing materials, many of which were tried and found satisfactory. Graphite and stainless steel were the final choice of several alternatives. The magnetic suspension with low operating pressures and no lubrication has proved to be the solution of the long quest of a maintenance-free bearing.

DAMPING SYSTEM

The damping system of the new meter consists of two small C-shaped magnets that are embedded as inserts in the die-cast aluminum-alloy frame as shown in the center of Figure 3. The magnets make use of the high energy and high-coercive properties of alnico V and as a consequence a large amount of damping is obtained in a small design. Die casting the magnets into position in the frame results in an assembly with the magnets fixed in position and surrounded by the aluminum die-casting alloy, which enhances the excellent surge-resistant properties of alnico V. This combination with the small size of the magnets has made possible the location of the magnets near the electromagnet, and yet they are immune to demagnetization from fields that arise from large short-circuit or lightning currents to which meters are sometimes subjected. The frame provides excellent alignment and support for the magnetic suspension and the moving element. The electromagnet and register also are located accurately by being attached directly to the frame.

ELECTROMAGNET

The electromagnet is excited by line voltage and load current. It generates in the meter disk a torque proportional to the power load. The new electromagnet provides this torque efficiently to give inherently small load, voltage, frequency, power factor, and temperature errors. The small inherent errors require only the minimum of compensation to provide excellent operation.

Performance is accompanied by a new high insulation level compatible with the general practice of installing meters out-of-doors and ahead of service entrance fuses and switches. The current coils are formed of bare copper wire. For assembly they are located with the electromagnet core in a mold that aligns all parts with proper spacings. Butyl

rubber then is introduced to the closed mold and cured in place. The result is an accurately and securely located current coil with the rubber providing turn, coil, and ground insulation. This is in contrast to the usual practice of using insulated wire for current coils. These in turn have had to be separated from each other and from the core, usually by some form of paper or fiber.

The butyl rubber has long-life properties even at the elevated temperatures to which meters sometimes are subjected. The molded-coil construction also contributes to low temperature rise and high overload capacity because of efficient heat dissipation.

For greater insulation strength, reliability, and secure positioning, the layer-wound potential coil, consisting of many turns of fine wire, is similarly molded to the electromagnet core. The molding material in this core is a polyethylene plastic of high dielectric strength and low moisture absorption.

Calibration and Adjustments. The adjustments are coordinated with the design to give long-time stability of calibration and precise adjustment. The main full-load adjustment made at the factory is accomplished by demagnetizing the damping magnets in the meter frame to give the proper disk speed at rated full-load power on the meter. This is made to within one per cent. For the final precise calibration a full-load vernier adjustment is used. This is a magnetic shunt that is moved to change the effective damping strength of the right-hand magnet.

The lag or phasing adjustment and the light-load adjustment are attached directly to the electromagnet. The lag adjustment, which is made only at the factory, provides the required phase angle of the useful potential flux to give the proper registration at all power factors. Adjustment is accomplished by severing portions of the lag plate to change its resistance instead of moving it to change its effectiveness. This insures stability of calibration. A temperature-sensitive magnetic core is included on the lag plate to maintain the phase angle over the operating temperature range. The light-load adjustment consists of a closed conducting loop movable transversely with respect to the electromagnet to provide an adjustable shading-pole torque that enables adjustment at light loads to close limits. This adjustment and the full-load adjustment are inherently fixed, once made, to give good calibration stability.

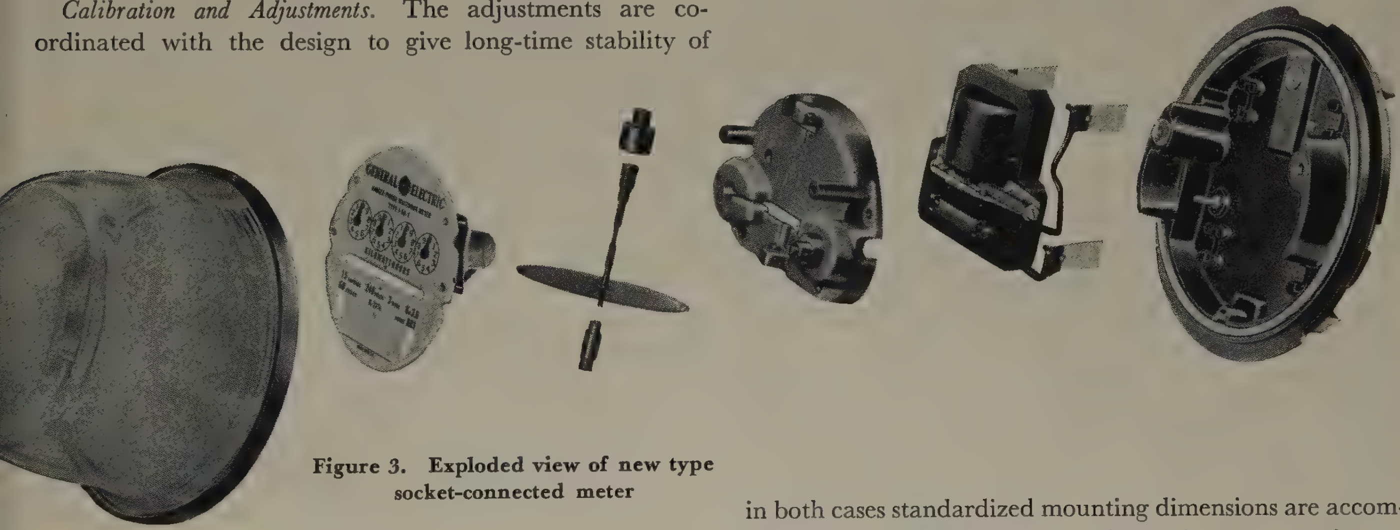


Figure 3. Exploded view of new type socket-connected meter

REGISTER

The register is furnished as either the pointer type or the cyclometer type. The pointer-type register employs a double-worm-gear reduction and bearings of stainless-steel pins running in aluminum to maintain friction at a negligible value.

In the cyclometer register friction has been greatly reduced by placing the number cylinders on vertical rather than horizontal shafts. A new feature employing magnetic storage and release of energy gives a positive reading action. Cylinders 2, 3, and 4 are advanced from digit to digit quickly as controlled by snap action occurring in the shaft assembly for cylinder 1.

BASE AND COVER ASSEMBLIES

The previously described components are supplied in socket or "plug-in" and in bottom-connected bases. Both types are required to fulfill various service requirements, and in both cases standardized mounting dimensions are accommodated. Much attention has been given to corrosion resistance in the selection of materials.

Both types incorporate co-ordination of insulation levels by constructions that provide relief gaps with a voltage breakdown level lower than the high insulation level of the electromagnet. Thus overvoltage breakdown is directed to the point where it will do least damage, and in most cases the meter will not be put out of service.

SUMMARY

The true significance of the *I-50* meter is that it is the first completely new meter in 50 years—new in its conception, its design, its operation, and in its use of modern materials and techniques.

Magnetic suspension answers the long-standing question of the lifetime bearing. But it also places a new emphasis on other design details, for the full benefits of the revolutionary moving system can be realized only in a meter with characteristics consistent with a lifetime bearing.

Added together, the new design features and the new materials and techniques combine to assure permanence and stability of calibration over long periods of time. They assure lower maintenance costs, greater ease in handling, and greater sustained accuracy than have been achieved previously in a watt-hour meter.

The Electrical Industry's Role in America's Destiny

PHILIP SPORN
FELLOW AIEE

The potentialities of the electrical industry in shaping the destiny of America are considered by Philip Sporn in this Steinmetz Memorial lecture, 21st in a series of lectures presented to honor both the memory of Charles G. Steinmetz and the selected speaker. The lecture is sponsored by the AIEE Schenectady Section.

AT THE OUTSET it is pertinent to ask, "What is the destiny of America?" The entire world, and more particularly the western world and our western civilization, today is facing a major crisis. The outcome of that crisis will determine, perhaps for centuries, whether that civilization will continue to new levels of progress and achievement, or whether like other civilizations before it, it will end in catastrophe and retrogression. If America has a particular destiny to fulfill it is to exert enough influence on history so that our present civilization not only will continue, but will ascend to new levels of progress and achievement. It can do this best by precept and example, by co-operation with other nations of like aims and objectives, and by giving help to those who need help. Above all it will help bring this about by building within its own borders a society that is strong, brave, and confident of its future; a society in which human welfare will be raised to levels where want, hunger, and fear will disappear, and yet one in which all this will be done without demanding of the workers labor so arduous as to leave neither time, energy, nor will for practicing and enjoying the spiritual and aesthetic activities of living.

Let us examine the nature of the crisis that is confronting western civilization. After a most brilliantly victorious but exhausting victory over fascism and naziism, the western nations confront a similarly victorious and perhaps even more exhausted totalitarianism—Russia and her satellites, our erstwhile allies. Each side is terrified by the growth in strength and influence of the other. Each distrusts the other, but perhaps for different reasons—and, if we can arrogate to ourselves the sole objectivity of judgment, we might add, with much more basis for distrust on our side than on the Russian. However, we ought not to expect the Russians to agree to this view.

The scene thus is set for an explosive act to bring about war, an atomic war, with all the tragic horror that will follow in its train. And if, aghast at the black prospect that this opens up, we were to resolve to embark on a course of conduct that would with certainty avoid such a catastrophe, we run into the other horn of the tragic dilemma, the conquest of the world by communism.

That this danger is real and menacing has come to be recognized comparatively recently. Only a short while before the outbreak of World War II, when the threat, horror, and barbarism of fascism were clearly discernible, many men of good will actually believed that the world could move into the plateau of permanent progress either through the pass of communism or the pass of democracy. Thus, Casson, while fully alive to the sterility and destructiveness of fascism, to the fact that it was a movement and a creed which was the direct opposite of the great civilizing experiments of the past, and that it had nothing to offer mankind for the future, still believed that communism was like democracy in this respect: each sought to bring about a world in which progress is possible. True, there would be some differences: democracy would unite mankind according to mankind's own wishes, permitting each separate region to live as it wills, while communism would unite mankind on a basis of uniformity, perhaps forcible uniformity. But each offered, according to Casson, the fundamental unifying force for the existance and development of a human civilization. During the war, when our great need for allies in the struggle against fascist barbarism naturally blinded us to some of the glaring divergences between fact and its idealization, many others, normally more discerning, adopted this same view.

Actually, as is evident today, democracy and communism are too far apart to offer joint or parallel paths to the road of progress. The apparent ability of communism to unite mankind is bound to end in failure because of the inherently divisive nature of communistic doctrine and dogma inherited from the almost mystically revered "Communist Manifesto." The notions that as the use of machinery is developed the burden of labor will be increased; that the petty bourgeoisie will be swallowed up in the proletariat; that the worker has become a pauper and that pauperism is increasing even more rapidly than population and wealth; these doctrines clearly have been disproved in the most highly developed capitalist countries. They are, however, today's unchanged communist doctrine. They are untrue; that, however, does not prevent their being used today as a corrosive agent to undermine the supporting structures of anciently established national groups in order to advance the boundaries of the world's area controlled from today's center of communistic faith and dogma. But the vitriolic intolerance for dissidence of opinion, the fanning of the flames of class antagonism, the suppression of basic freedoms, these cannot in the long run offer a cementing force of sufficient permanency to develop the unity of mankind which is so necessary a condition for progress.

Essentially full text of the 21st Steinmetz Memorial lecture, "Potentialities of the Electrical Industry in Shaping the Destiny of America," which was delivered at Union College Memorial Chapel, Schenectady, N. Y., May 20, 1948.

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Yet, it must be admitted that in seizing upon, and underlining the fact of class antagonism, communism at its birth grasped at a truth. The antagonism between master and slave of Roman times carried over into the era when the organization of society was on a master and servant basis. It did not disappear when the servant disappeared and there emerged the industrial worker. The doctrine that as industrialization develops the worker becomes pauperized has been proved to be fallacious. On the contrary, the record is clear that as technology has developed, the minimum standard of living has risen to heights unimagined only a generation or two previously. This should have eliminated entirely the evil of class antagonism. That it has not done so at all in many countries, and has not disappeared entirely even in the United States, is proof of the virility of this antagonistic feeling and of the need of continuing the battle to unify mankind.

If democracy is to grow and flourish and bring forth the fruit of human co-operation requisite to a unified civilization, it must be rooted in economic well being and social justice—and the latter is of no avail if the former is at bare subsistence level. If democracy is to triumph, if free man is to reach out for the stars our economic system must travel along the path of increasing productivity and increasing well being of the individual, that is, of greater availability to the average man of the products of earth and hand and the machine. While that is being accomplished, it is imperative that to the fullest extent possible it be accompanied by lessening the burden and toil of the individual, or at the least by the elimination of that part of the individual's job in which he is used merely as an energy producer. With it must go a recognition of the depth of the human demand, the almost instinctive and passionate urge, for social justice. It will be necessary therefore to be on the alert for injustices, and for inequalities that have no social-economic basis, and to eliminate them or to mitigate their effect. However, this phase can be dealt with as we elevate the level of well being of the social unit as a whole, by increasing its productivity.

What is the destiny of America? Its destiny was formed at Valley Forge, forged at Gettysburg, and tempered in the blood of its sons who successfully fought rising tyrannies in two world wars. Under a system guaranteeing the individual life, liberty, and the pursuit of happiness, its citizens have developed their agriculture, industry, and commerce, and their level of physical welfare to the highest point reached on the face of the earth. This is the torch which America has held up before the world as a flaming beacon. It is in the preservation here and the expansion throughout the world of these ideals of human freedom and welfare that America will fulfill her destiny.

THE ROLE OF THE ELECTRICAL INDUSTRY

It is here that the great opportunity for the electrical industry lies; here, in extending and developing our industrial system by the use of more extensive, more skillful, and more intensive applications of electrically powered machines and tools to increase productivity and to make more of the products of these machines and tools available to man; in bringing about more intensive and more intelligent cultivation of the soil to increase the fruits and products of the soil while reducing the effort and labor exerted, and so make available more food, without which man will perish, while raising the condition of living of those engaged in farming so as to bring the spiritual products of our civilization within their reach; in improving living in the home so as to make the home a more comfortable, a more relaxing, and a more spiritual environment for all the members of the family; and finally, in making the nation strong, so that strong and confident in its strength, but guided by modesty and justice, it can co-operate with other nations, help them to live, but also be assured of its own ability to live and survive. It is in these four fields—industry, farm, home, and nation—that the electrical industry—the machine, tool, and appliance builders and the manufacturers and suppliers of electric energy—has an opportunity to play a vital part in shaping the destiny of America and thus of the whole western world. A large part of the world is looking toward America to show the way; it is hoping and praying for America to succeed, and it would view as its own major tragedy America's failure to succeed.

Let us review briefly America's contribution to the world's industrial and farm economy, appraise the accomplishment of the electrical industry, and from that try and chart the course of opportunity open to the electrical industry. With approximately 1/15 of the world's population, about the same proportion of its land area, and little more of the world's natural resources, the United States today produces one-third of the world's annual output of goods and services. No less an authority on waging war than Stalin is author of the statement that it was American war production that tipped the balance against, and insured the defeat of, the axis nations. This, however, was no sudden miracle. The productive achievements of 1944 were the culmination of a century of progress and growth in industrial production. Between 1850 and 1944 our population increased about six times, our labor force a little more than 8 times, and our total labor output about $5^1/_2$ times, but the net output of American industry was about 29 times larger in 1944 than in 1850. Thus the productivity of human labor or the output per man-hour for the economy as a whole, showed a fivefold increase during the period of less than a hundred years ending in 1944. The study made by Snyder of national income and wage and salary payments through this same period has shown clearly that there exists a close and almost unchanged relation between national income, that is the well being of all the population, and wage and salary payments of people in industry.

Because of the limited ability of the human body to produce useful work, the progress in output per man-hour is almost directly related to the increasing use of power-driven tools and equipment. Originally these were mostly altogether mechanically driven tools, but they have become more and more electric until today the electric portion constitutes almost 93 per cent of the total. It is interesting to examine the figures on the amount of power and power-driven tools that have backed up the American worker over the past century. Here are recent data:

1849—very little
1879—1.3 horsepower

1909—2.9 horsepower
1929—4.86 horsepower
1939—6.4 horsepower
1947—7.2 horsepower

These figures indicating more than a fivefold increase in the period 1879–1947 leave no room for doubt that American productivity and individual well being closely are related to the lavish use of tools and equipment and the energy needed to drive these tools. Nor of the fact that if more is to be produced per unit of human labor more tools and more energy to drive them will have to be employed, and that means electrically driven tools and electric energy.

However, are there opportunities in our competitive system for further application of tools and power that would be sound from an economic point of view? An examination of the entire field of industry shows amazing opportunities and potential applications of vast proportions. Not only will electrical applications be required in the normal expansion of industry resulting from population growth and the expanding of all existing industry to take care of this additional population, but special and new applications in such industry, and many heavy energy using new industries will further add to the total. Thus, in each of such relatively new applications as radio-frequency heating, electric furnace brazing, infrared heating, and continuous annealing of metal products, annual increases in demands varying from 10,000 kw to 200,000 kw can be anticipated in the next ten years. In the same period such established processes or industries, all of them heavy energy consumers, as welding, electric arc furnaces, resistance furnaces, reduction of aluminum, and reduction of magnesium can be expected to call for an annual increase in power demand of from 40,000 kw to 500,000 kw. Whether some of these demands best can be, and therefore will be, supplied by the industries originating them, is not too material; the electrical opportunity will be there in any case. Besides these there will be increased demands in coal mining, ore beneficiation, fertilizer, and similar industries that each will require or may require perhaps an average of 100,000 kw per year over the next decade. The load represented by the sum of all these discloses an opportunity for the electrical industry over the next ten years which, when measured by electrical demand, totals an annual increase of between 1,500,000 and 2,000,000 kw.

In the study of the history of past civilizations and of man's progress and retrogression the part played therein by the condition of his food supply must not be overlooked. As a matter of fact, it has had superimposed on top of its cyclic variations a consistent, continuing, and vital trend; the race between population and food supply. In the United States this race has not been so noticeable heretofore because of the fortunate condition thus far of the ratio between population and arable land, but in other large sections of the world there is already an unbalance between population and the soil available to support it.

At the present time the United States is exporting large quantities of food. These have played and are bound to play for some time to come a major role in repairing the havoc wrought by the last war and in helping build up large segments of the western European population to positions where they can be substantially self-sustaining. If this country is to continue to be able to do this in the face of our own rapidly increasing population, it will be necessary to increase its agricultural output. To do that in the United States presents, however, a particularly difficult problem. In the quarter century ending with 1945, while the population of the country increased from 106,500,000 to 139,600,000, an increase of approximately 31 per cent, the farm population declined from 31,600,000 to 23,600,000, a decrease of 25 per cent. In the same period the percentage of the farm population to the country as a whole declined from approximately 30 per cent to 17 per cent. This trend has been arrested temporarily, but it is evident that here in the United States, as in other countries, if more food is to be produced, more output per man will have to be obtained and more tools employed. Other factors will have to be changed without question: more and better fertilizers will be needed; more intensive farming will have to be practiced; higher yield and improved crops (like hybrid corn) will have to be resorted to. But there still will be the problem of increasing the output of farm commodities per man or per man-hour, and here again the electrical industry will have to play a vital part.

ELECTRIC POWER ON THE FARM

Admittedly, farm mechanization is not as dependent on electric power as is industry in general, because of the economic position that the internal combustion engine holds on the farm. It is only when you analyze the multitude of chores that have to be performed and the effect that the efficient performance of these has on the acreage that economically can be integrated in the single family farm unit, that the importance of electric tools and electric energy on the farm is seen in clear perspective. What then are the electrical opportunities here?

In the face of the remarkable progress made in bringing about the first step in rural electrification in the last decade, it is evident that mere electrification is not the avenue of approach—thus, with a record of some 3,817,000 farms electrified by the end of 1947, another 460,000 expected to be electrified in 1948, and still another 750,000 reached by existing lines and not yet taking service, a bare 500,000 to 600,000 farms will remain to be reached in subsequent years; the job of initial electrification of the country's farms is, in other words, 90 per cent completed.

It is in farm utilization figures that the story of opportunity is told. The story of these over the past 20 years is significant. They are

1926—2,339 kilowatt-hours per farm customer per year
1931—2,688 kilowatt-hours per farm customer per year
1936—2,050 kilowatt-hours per farm customer per year
1941—1,574 kilowatt-hours per farm customer per year
1946—2,182 kilowatt-hours per farm customer per year

It is not too difficult to account for the decline in utilization in the 15-year period 1931–46 when it is realized that in the same period there occurred a trebling in the farms electrified. It is more difficult to become reconciled with the average annual use for 1946 in the face of corresponding figure of more than 1,300 kilowatt-hours for the average residential home. What is the explanation? A number of

reasons occur: the only relatively recent general availability of electric power on the farm; the backwardness of electro-agriculture engineering; and the intervention of the war.

At present, however, there is every reason to look forward to development of special electric tools and services in every branch of farm activity; in the home, to perform most of the operations electrified in the city home; in crop processing, to carry out drying, baling, cropping, grinding, crushing, husking, vining, conveying and many other related operations; in dairying, to milk, wash, boil, sterilize, pasteurize, cool, freeze, churn, separate, agitate, pump, ventilate; the list is almost endless and it extends into the other branches of farm activity. The opportunities open here are so great that there should be no real problem in doubling the average farm utilization in ten years, and doubling it again in another ten. When we have reached that point, the annual kilowatt-hours required by our agriculture will be approximately 45,000,000,000 kilowatt-hours; this is more than 20 per cent of the total energy furnished to every type of consumer by the power systems of the United States in 1947.

The gain to be achieved by grasping the opportunity to extend electric applications on the farm goes beyond mere more production per man-hour and more intensive cultivation of the land; it goes to the heart of stabilizing and assuring farming as a part of a balanced social-economic scheme in a democracy. The only certainty of steering clear between the Scylla of a peasantry and the Charybdis of a communized agriculture, either of which would be disastrous to democracy, is to encourage the maximum development of a farm population as a sturdy, productive unit of the social-economic structure and as a fully integrated and indispensable part of our society. The fact that more extensive and intensive electrification of work and living on the farm will be brought about not only will make farming a more productive enterprise, but will lessen human toil and labor. This will mean that the farmer and his family will be able to increase to a much higher level than today's their column of leisure, and thus their opportunity to participate in and enjoy activities of a broad communal interest, of recreation, self-improvement, and aesthetic enjoyment. Thus the barriers between city and country will be removed and a social cleavage so common in many European societies avoided.

ELECTRICITY IN THE HOME

The family is our basic social unit and its habitat is the home. Here are not only congregated for the largest percentage of their total time the group constituting the unit whose members are tied to one another by the strongest of human ties, but here also are developed the attitudes of its members toward society and the social-economic system which most often are capable of only minor mutations in later years. Here, rest and relaxation and surcease from toil are found by every member of the family no matter what his place in the social system—worker, professional man, or businessman. Rest and relaxation, however, are not promoted by conditions in the home calling for the efforts and exertions of numerous members of the family to carry out operations and perform functions that are basically chores or that call primarily for energy exertion, nor is a physically uncomfortable home especially conducive to spiritual harmony. Yet we find that although practically every home in the United States has been electrified and almost no homes are being built today without electric service, the utilization of electric energy in the home is still amazingly low. A series of figures on average annual consumption in the domestic homes of the United States over the past two decades are of interest in this connection:

1927— 450 kilowatt-hours per residential customer per year
1932— 600 kilowatt-hours per residential customer per year
1937— 805 kilowatt-hours per residential customer per year
1942—1,022 kilowatt-hours per residential customer per year
1947—1,438 kilowatt-hours per residential customer per year

It is true that this more than trebling in annual consumption in 20 years represents progress in utilization of electric devices in the home, but the progress has been slow and a great deal more needs to be done to accelerate the rate of progress. Essentially this gets down to the development of the proper tools and appliances and making them available for the average home. Instead of the average home having nothing more in the way of an appliance except a radio, an electric iron, 1/5 of an electric range, 1/15 of a water heater, and a toaster, it should have the service and comfort of the home laundry and the water heater, the electric range, the multitude of comfort-giving appliances, such as blankets, fans, space heaters, vacuum cleaners, and myriads of others, and with the development of television, very definitely the stimulation and enjoyment that is bound to come from the development of that art. If that is done, there is no reason why the average utilization cannot come up within a decade from the 1947 figure of 1,438 kilowatt-hours to 2,600 kilowatt-hours, and by 1967 to a figure of 4,800 kilowatt-hours per year.

All this is based on heating and cooling of the home remaining in status quo. But why should heating and cooling remain in status quo? Is there any other operation in the average home with the possible exception of the preparation of food that is more important than heating and cooling, and is there any reason why electricity, which admittedly is the cleanest, the most readily available, and the safest form of energy, should not be used for performing that most important single utility function, if it can be done economically? The answers to both questions are, "No." But unfortunately the heat pump is not yet ready to be offered for use in the average home.

Progress in its development is being made, however. By the end of this year we hope to have at least ten heat pump installations, of designs that give excellent promise of being successful, installed in typical residential homes. This, too, has taken too long, though, and the rate of progress needs to be accelerated. If you keep in mind, however, that the heat pump installation in an average home will require not less than 10,000 kilowatt-hours per year, and if you assume that ultimately 10,000,000 homes will be equipped with heat pumps, you get an increased domestic consumption of 100,000,000,000 kilowatt-hours per year on that account alone. Suppose it can be brought about within the next 20 years. What a magnificent

opportunity that is when you consider that the present, that is, the 1947, total energy generation in the United States for all purposes was only 255,000,000,000 kilowatt-hours!

There is another important phase of the heat pump that needs pointing out: that is the effect its extensive use would have on our supply of natural resources, not only fuel, but a number of our other basic resources. However, this phase will be treated as part of the discussion of the opportunities open to the electrical industry in the field of national defense.

ELECTRIC POWER AND NATIONAL DEFENSE

The fourth avenue of opportunity for the electrical industry is that of national defense and national security. During the last war, and particularly at the peak of the war, we out-produced the axis nations in combat munitions by more than 50 per cent, and we alone accounted for nearly 45 per cent of the armament output of all belligerent nations. Yet we did this with only about half of our productive power devoted to governmental requirements, and the remaining half was adequate to maintain a civilian standard of living at almost the highest prewar level ever achieved. In a large measure, we achieved this as a result of the high degree of mechanization and the large amount of power and power-driven tools that were available to back up the American worker, a figure that during the war was of the order of seven horsepower per worker. The power to run that seven horsepower, in turn, was available because of the magnificent job that was done by the electrical industry during the war, aided by the margins in capacity above loads with which the power systems entered the war period.

We just have started a program of again building up the defenses and the armament of the United States. To take care of those new developments that will be brought forth in connection with this armament program, and to be ready for such contingencies as may develop, it will be necessary to have an adequate supply of power, with margins more generous than those that are now available. And this is again an opportunity for the electrical industry.

It is almost trite to say so, but it is true nevertheless, that no modern industrial nation is any stronger than the supply of raw materials with which to run and operate its industry. Under the discussion of the industrial opportunities open to the electrical industry, ore beneficiation and the electrical requirements that this will bring about were mentioned. Our reserves of high grade iron ore, particularly in the Mesabi region, rapidly are approaching the stage of exhaustion and will be only an item of history in the not too distant future. Thus, as long as steel continues to play the part that it does today in the whole industrial structure, we will have to rely more and more on lower grade ores. Both from an economic standpoint and to conserve as much of the high grade ores as is still possible at the present time for extraordinary conditions, it is highly important to strike a better balance in their application than has been struck heretofore between steel and the lighter metals, specifically aluminum and magnesium. The development of these metals, in turn, offers an opportunity for the electrical industry to make a major contribution to national defense.

Again, our economical reserves of copper are today depleted so that only perhaps 25 years' requirements are left. We had to import copper to carry us through the late war. Our electrical industry is based upon copper and would today come to a standstill without it. And the electrical industry, through its machines and the electric energy that operates them, furnishes the bone, the muscle, and the life-blood for most other industries in the country. If we are to extend the life of our present reserves, it is again necessary to introduce, and as quickly as possible, the use of other metals, and particularly aluminum, so as to have copper available for those applications where we as yet have found no substitute for copper. That transition is going on now, but an acceleration of that process is needed; its realization will be another addition to the national defense.

The importance of fuel in the national economy is not half enough appreciated by even the intelligent lay people, nor has the abundant supply of all fuels—coal, oil, and gas—been given enough credit for the industrial pre-eminence and for the high level of economic welfare of the United States. Yet our proved reserves of petroleum, while standing close to an all-time high, within a decade or so may reach the scarcity basis. Our wanton use of nature's rich gift of natural gas may have been abated somewhat, but many of our fields now are exhausted, and we still use by and large the least valuable portion, the thermal part, of a complex and valuable chemical item. In our coal fields nature has been particularly lavish and kind. Yet we have exhausted many of the best deposits. Until a short while ago, it was common opinion that our reserves were ample for from 2,000 to 3,000 years' use. This is not a limitless supply, but seemed to be one sufficiently large that we could appear almost indifferent to the efficiency at which coal was being utilized. That certainly is not the situation today. The time for complacency definitely has disappeared, and in its stead it is necessary to take a more sharply appraising look as to how best to utilize the more modest reserves that we more probably possess. Crichton, in a recent survey, has indicated his judgment that the total coal reserves available in the United States are only sufficient, at present rates of production and rates of mining, for the next 250 years, and that in the highly industrialized east where 92 per cent of the coal is produced and used, we have only 90 years' supply. It is obvious that more study of this question is justified; but if the actual conditions are anywhere nearly as critical as is indicated by these figures, then here is one of the very great opportunities available to the electrical industry, and it is a 3-pronged fork. First, to improve methods of mining and rates of recovery of existing resources by better machines, tools, and processes, and in all of them electric power will play a most vital part; second, to improve prime movers and the efficiency of conversion of the fuel to electric energy; and finally, to improve the utilization devices, so that the same work or function will be performed at an expenditure of less energy, and therefore less fuel.

THE HEAT PUMP

It is most significant that in this connection the heat pump and its development has within it the seed of two large social-economic and long-term gains, both bearing on conservation and, therefore, on strengthening national defense. First, a coefficient of performance of 4.0 means a striking increase in the life of all available fuel resources. In fuel-burning electric energy generating plants over-all thermal efficiencies of approximately 40 per cent are within sight. If the electric energy for use to operate heat pumps with a coefficient of performance of 4.0 to heat our homes, commercial establishments, and offices is generated at that efficiency, the net result would be delivery to the heating coils of 160 per cent of the energy originally resident in the fuel. Thus at one stroke the potential life of our present fuel resources, certainly of that portion devoted to home heating, greatly would be extended, perhaps to a figure double of what otherwise would prevail. Second, if the heating of homes by electricity is assumed as an inevitable ultimate development, it is important to note that the heat pump with its coefficient of performance of 4.0 would reduce to one-quarter the copper otherwise needed for the transmission and distribution of the power devoted to that purpose. The limiting of fuel burning to efficient, centralized plants, the further harnessing of the power in rivers and streams, the development of the potentialities of wind power and of nuclear fission in the future are all corroborative of this outlook on the future of electric heating and the contribution to the conservation of our copper resources, and of aluminum resources which this will bring with it.

Finally, national defense will be strengthened, perhaps to a greater degree than by any other single contribution, by developing a strong, healthy society that is highly productive, one that has the food necessary to sustain it supplied by a well-integrated farming population, and where the home continues to be the center of living activity, in short, a society that is healthy, happy, and that lives in harmony with itself and with the world at large. Such a society will be strong and will be able to defend itself. In making its contribution to help bring about such a society, the electrical industry can make the greatest contribution to national defense.

QUALIFICATIONS OF THE ELECTRICAL INDUSTRY

How well is the electrical industry set up to grasp this golden opportunity to help shape the destiny of America? Is all well? Is the probability of the now wide open opportunity being seized and developed good enough so that we can count on it as an almost certain eventuality, or is there need for further preparatory work?

A careful examination of the problems involved leads to the clear conclusion that things are far from well, and that it would be folly to proceed on the assumption that the process of exploiting the opportunities open to the industry will be an automatic affair. There are too many things still to be done, too many attitudes to be changed, too many shoals to be navigated, before we can be sure of reaching safely the much desired shore.

We have, for example, a great deal of research ahead of us. If the opportunities so manifestly open to the electrical industry are to be exploited it will be necessary to fill in some of the wide gaps in our science and in our technology. We can do this if we carry on the necessary research, and some of it is going on. But if the fuel problem, for example, is to become more critical, then the reasons for more intensive work on new and improved thermal cycles and for higher temperatures in power generation by steam become more urgently persuasive. Higher levels of energy utilization will require, if they do not already do so, higher transmission voltages to transmit the larger blocks of power from generation to load centers and to furnish greater capacity interconnection facilities between generation centers and between adjacent systems. The increased loads in the service areas, if economy in distribution is to be maintained, will require new ideas, methods, and techniques in distribution. More extensive utilization of energy on the farms and in our homes calls sharp attention to the need of more research and development work on many farm devices and on home appliances to produce them at lower and lower costs to make possible more wide-spread distribution. There is an urgent need to concentrate major effort on the development of the heat pump.

Again, it is necessary that we change our entire attitude toward fuels: their general availability, the availability of different classes for the tasks they have been traditionally performing, the possibility of displacing some of them with fuels of lower quality, and the fullest economic exploitation of all of them. For example, I doubt whether many people in the electrical industry, or the coal industry for that matter, have given much thought to the very important fact that the additional steam-turbine-driven generating capacity under construction and to be constructed in the four year interval 1948–1951 still, even after allowing for a much greater margin of reserve in 1951, will require at the end of that year approximately 24,000,000 more tons of coal than were burned in 1947 for power generation. The satisfactory working out of the fuel problem, and of the problems arising from the fuel problem, will take much pioneering, patience, development work, and teaching.

The very magnitude of the opportunity for shaping the destiny of the country, open to the electrical industry and lying ahead, carries the seed of its own frustration and the throttling of its development. It now appears as fairly certain that by 1952 the electrical development of the country will result in a power demand of 66,000,000 kw. Now while it is necessary to have generating capacity to meet such a demand, the demand itself can come about only if the tools, devices, and appliances are developed, installed, and utilized to bring about the demand. A projection of the presently known curve of growth of the power industry on a much moderated basis, but taking into account the fruition of the opportunities for extending electrification in the many fields discussed, indicates a demand for 1957 of 86,700,000 kw and two years later a demand of 96,800,000—practically double the 1947 figure. The danger here then is that not believing such growth will take place, failure to make and to execute the necessary plans requisite to its consummation will result; this by itself will stifle the growth. If growth takes place

in spite of lack of preparation or complete preparation, up to the maximum possible under such adverse conditions, there is still the danger that it will be a halting and uncertain growth and that it will contribute, therefore, only a part of its full potential to the social economic welfare of the country.

Another danger, perhaps only slight now, yet one not to be overlooked, is the prospect of more direct and extensive incursions by governmental agencies into the electrical industry. The industry has reached its present phenomenal development as the result of private invention, initiative, daring, and enterprise. The currently still limited participation by governmental bodies in the field so far have had no material sterilizing effect on progress and invention in the industry as a whole, but it is hard to visualize how such sterilizing and retarding effects would be kept out if more extensive inroads by government agencies were to take place.

Despite all obstacles that may prevent it, the problems confronting the electrical industry in its exploitation of the opportunities open to it will be solved. Our industrial system, now the envy of the world as a mechanism for producing goods and services for the use of man, will be stimulated to greater achievement—to greater production, with lessened toil by the workers, and greater availability of the products of their toil to those who produce them. Our soil will be made more fruitful and those who cultivate it not only will be able to maintain and even raise the level of their economic well being, but they will become more closely integrated members of the national community. Living in the home will be made easier, more comfortable and this will serve to strengthen the position of the family as the basic social unit. The nation and its defenses will be strengthened, its resources will be husbanded, and this will not only contribute to national security and defense in the relatively immediate present, but to the welfare of future generations.

Thus strengthened, America need not face its future with dread and fear. War with all its catastrophic consequences need not be looked upon as inevitable and, with careful guidance, can be avoided. By staying strong and productive, by raising the level of well being of its own people and mitigating or eliminating entirely social injustices among its citizens, by helping those in other countries to reach the same objectives, America can reach a position of influence and respect among the nations of the earth where it will need have no fear of the undermining of its social economic system. The prospect of our present civilization continuing to new heights of achievement thus would become bright indeed.

That is the destiny that beckons America. And the electrical industry has an unparalleled opportunity to help shape that destiny. In that regard its potential influence is out of all proportion to its size, to the number of people engaged in it, or to the capital represented by its shops, tools, plants, and equipment. It is rather more like fire, between which and electricity—the modern fire—there is a close affinity. When Prometheus brought fire to man he brought him what was without doubt the supreme gift. With fire in his full possession man would be able to win the secrets and treasures from the earth to develop science, commerce, and the arts. Our modern fire has lost none of the potency of the Promethean, nor the potentialities for improving the welfare of man.

Illuminating Laboratory Models

These are models used in the General Electric Company's illuminating laboratory in Schenectady, N. Y. The one at the left is used to demonstrate the effects of different kinds of street lights on driver and pedestrian visibility, and on adjacent buildings. At the right is a tunnel model which is useful in studying the highly specialized problems of obtaining good tunnel lighting without glare in installations throughout the country

Statistical Methods in Wire and Cable Processing

M. G. WOOLFSON
MEMBER AIEE

MANY OF THE PROCESSES in the manufacture of wire and cable and tests of the finished product are amenable to control or study by recognized statistical methods. The scope of these applications is indicated in part by the following.

Machine control charts (for measurable characteristics):

1. Weights per thousand feet of concentric stranded and crushed conductors.
2. Thicknesses of walls of paper and varnished cambric insulation.
3. Dimensions of extruded insulation.
4. Eccentricity and thickness of lead sheaths.

Bar charts:

1. Classified abnormalities found on inspection of adequate samples or large lots of finished product (single or multiple sampling method).
2. Causes of rejection in mass production operations.

Frequency distributions (histograms):

1. Periodic summaries of the data used for plotting machine control charts, to show material usage, and actual frequency distributions of cumulative data, and to compare performance by shifts and by machines.
2. Studies by dimensions and/or weights of the component parts of finished products.
3. Summaries of continuing records of test data such as mutual capacitance of pairs of conductors in telephone cable; ionization tests of paper-insulated oil-impregnated lead-sheathed cable; and physical tests of bare wire, rubber, and synthetic compounds.

p-charts (fraction defective, that is, ratio of number of defective units to the total number under consideration):

1. Preliminary and final electrical tests of rubber-insulated wires and cables.

C-charts showing the number of defects in samples of constant size have been used on rare occasions, but for cable manufacturing they appear to have somewhat limited value.

From a practical standpoint machine control charts for $\bar{X}$ (the average or arithmetic mean of a set of observed values) and R (the range, the difference between the largest observed value and the lowest observed value in the set from which $\bar{X}$ is determined) have been found most satisfactory because of the facility with which they can be introduced and used. Three, sigma upper and lower control limits almost always are used. Sample groups of four are used without exception.

Figure 1 shows a continuous vulcanizing machine control chart for $\bar{X}$ and R of over-all diameters in per cent of nominal for insulated wire (numbers 12 and 14 American wire gauge conductors with 2/64-inch code rubber insulation.) The chart covers 29 successive days of operation.

Two alternative methods are suggested for the control of eccentricity of lead sheaths:

1. Determining eccentricity of specimens (rings of lead) by taking ten micrometer caliper measurements equally spaced circumferentially in accordance with the procedure outlined in the Association of Edison Illuminating Companies' specifications for "Paper-Insulated Lead-Covered Solid-Type Cable" (seventh edition). In this case eccentricity is computed using the formula

$$\text{Eccentricity per cent} = \frac{\text{average} - \text{minimum}}{\text{Average}} \times 100$$

2. Visually examining the cut ends of the control specimens (rings of lead) to locate the thinnest and heaviest arcs and exploring these by micrometer caliper to obtain the actual minimum and maximum thickness. Eccentricity then may be computed using the formula

$$\text{Eccentricity per cent} = \frac{\text{maximum} - \text{minimum}}{\text{maximum} + \text{minimum}} \times 100$$

Figure 2 shows a typical control chart for eccentricity of sheath extruded from a vacuum-type lead press, for cables having cores exceeding 2.0-inch diameter, and sheaths of nominal average thickness greater than 95 mils. Several types of cables have been combined. The period covered by the chart is three consecutive days of operation. Fifty-seven individual determinations are involved.

Digest of paper **48-176**, "Statistical Methods as Applied to the Manufacture and Testing of Wire and Cable," recommended by the AIEE subcommittee on statistical methods of the Standards committee and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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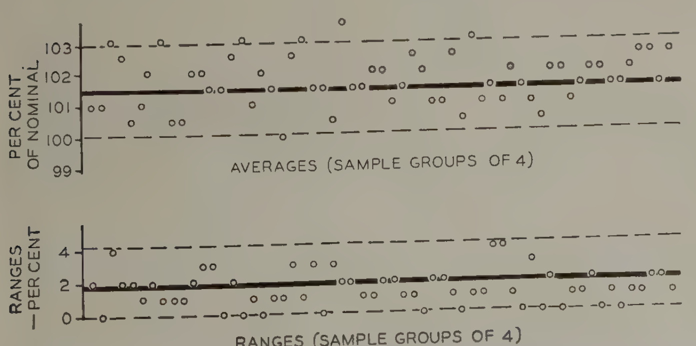


Figure 1. A continuous vulcanizing machine control chart of over-all diameters in per cent of nominal of insulated conductors

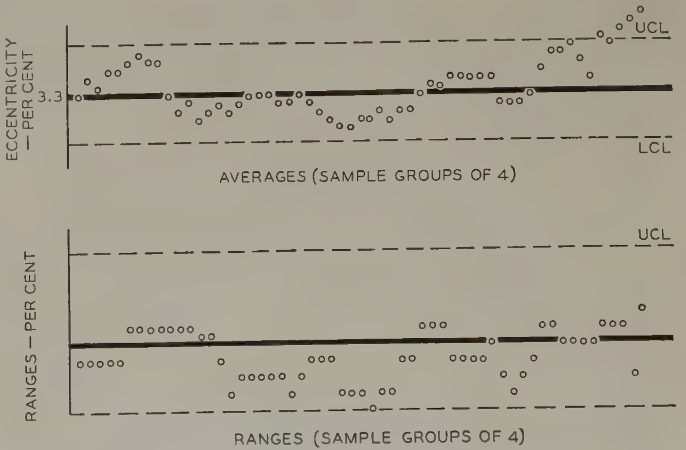
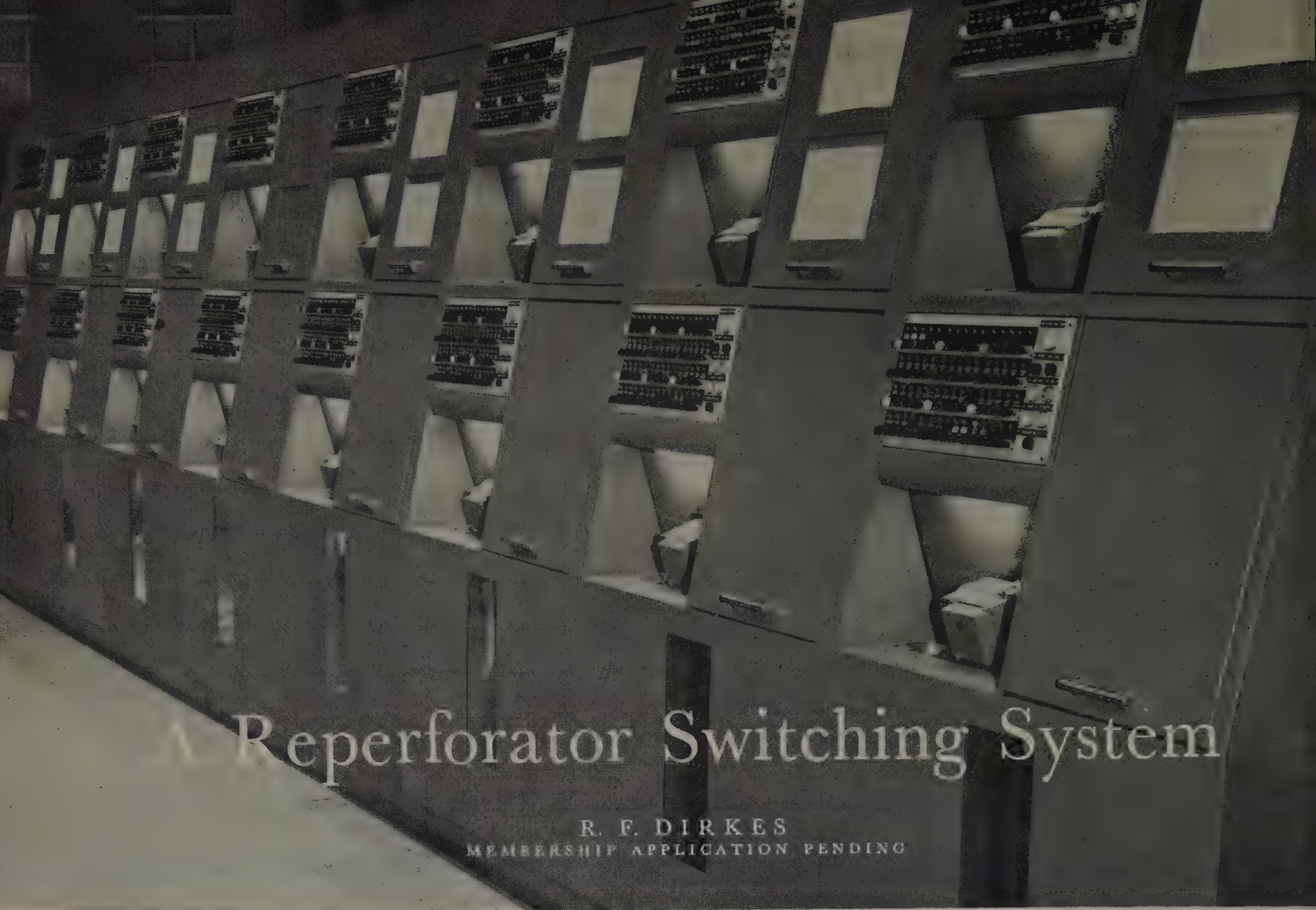


Figure 2. A typical control chart for eccentricity of sheath extruded from a vacuum-type lead press



A Reperforator Switching System

R. F. DIRKES
MEMBERSHIP APPLICATION PENDING

THE urge for greater economy, accuracy, and speed of service in handling telegraph traffic has created great interest in the use of reperforator switching systems for relaying messages. The Western Union Telegraph Company is in the process of installing in many large cities reperforator switching arrangements which, in combination with an extensive wire carrier and radio beam telegraph system, will handle practically all of its telegraph traffic. Western Union also has designed and installed a large number of successful private wire systems on the premises of its patrons for the handling of their intracompany traffic. The purpose of this article is to describe the planning and principal features of Western Union's most modern patron switching system which will handle efficiently the telegraph traffic of a typical large business organization.

PLANNING

Important in the design and operation of a system is the size and correct location of the switching centers. Center locations may be dictated partly by the geographical structure of the organization to be served. However, circuit economies and handling savings well may indicate the need for a center in a city where the prospective patron has no office. Obviously, therefore, a most necessary function before deciding on switching center locations and their size, is the conducting of a complete traffic load study. To this end, the load is sampled over a period of three representative working days. A copy is kept of every message sent during this period from every city involved.

These messages are processed broken down into numbers of words, and finally incorporated into a chart called a crisscross, a section of which is shown in Figure 1. This is a primary step in preparing the data in form for ready reference so that a circuit layout study both from the standpoint of efficient traffic handling and circuit economies can be made. Presuming this to have been done and size and location of switching centers determined, space layouts are next in the order of importance.

Not only should the layout be designed to provide efficient message switching but also careful consideration should be given to the proper processing of the messages terminating in the switching center. Access to these messages for final delivery shoud be made as convenient as possible. Delivery to the center of messages to be sent should also be considered. Not to be overlooked are simplification of cable runs as well as equipment maintenance.

A floor plan of the space to be used is, of course, essential. This should include exact location of doors, lighting fixtures, windows, radiators, and any other permanent fix-

Essentially full text of a conference paper, "Modern Reperforator Switching System for Patron Telegraph Service," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948; and not scheduled for publication in AIEE *TRANSACTIONS*.

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The extreme competition in business today has advanced communications to a key position in all industry. The use of the modern reperforator switching system for patron telegraph service makes possible more efficient and reliable intercity communication within a company.

tures in the space involved. It is our practice to prepare an accurate floor plan on a scale of one half inch to a foot. This floor plan is crosshatched with a line every half inch. Models to the exact scale of one half inch to the foot of all cabinets, printer consoles, tables, chairs, switchboards, rectifiers, and so forth are placed on the floor layout in various combinations and arrangements, giving full consideration to the factors previously mentioned.

Figure 2 shows a typical layout of a small switching center. Note that a table for processing messages is situated near the door so that the pickup and delivery can be made without having messengers enter the operating areas. Local receiving and sending teleprinters also are situated near the delivery area.

The maintenance table and control cabinet as well as switchboard and rectifiers are in an area remote from the ordinary operation. Clearances between cabinets and walls are adequate for the maintenance of equipment.

Note the ease with which the layout problem can be grasped because of the third dimensional quality of the display. This method of layout study and display has been found to be especially valuable where discussions are carried on with personnel unfamiliar with the reading of blueprints.

OPERATING ROUTINE

In any message switching system, the importance of an efficient operating routine cannot be overstressed. The finest equipment may prove inefficient without strict adherence to a practical and properly designed operating routine. Obviously, operating routines will vary depending upon the type of traffic being handled so no attempt will be made to describe a complete operating routine. Paramount in operating routines, however, is the rigid observance of a standard message form. Irrespective of the type of business involved, such a form, generally speaking, will follow a certain line or pattern. Therefore, I have illustrated a suggested form to which I will refer in further explanation of the operation of the switching center to be described. Figure 3 shows a typical form for "on line" or "system" messages. Particular attention is directed to the first line which reads *CHGO NWYK 52 6*. This indicates that the message is destined to Chicago, Ill., and has originated in New York, N. Y., as the 52d message of the 6th day of the current month. No further information is needed to define this message completely in the event later reference to it is necessary. The second line indicates that the message is directed to the passenger agent in Chicago. This information is needed for final delivery but not for routing or switching.

At the end of the message, after the proper spacing for tearing off (if such spacing is desired), note the addition of a switching control signal consisting of two carriage returns and two letter combinations. The function of this signal is to denote the end of the message for automatic stopping features later to be described.

In a switching system messages are received on a printer-perforator. This machine prepares a perforated tape with printed characters on the upper edge of the tape directly above and in register with the perforated combinations. A copy of message *NWYK 52* in the printer-perforator tape form is shown in Figure 4. The first intelligence characters appearing in the tape show the destination address, followed by characters which show office of origin, identifying message number, and date. Attention is directed to the switching control signal at the end of the message.

Having in mind the general message make-up and its counterpart in the perforated tape, the operation of a switching center now may be studied.

PLAN 51 CENTER

Obviously, the result of preliminary study may have indicated a system employing centers of two or three types operating together. Economies may have dictated even manual handling in some places.

	ATLANTA	BALTIMORE	BOSTON	BUFFALO	CHICAGO	CLEVELAND	DALLAS	DENVER	DETROIT	ELKHART	FRESNO	GIBSON	HOUSTON	INDIANAPOLIS	KANSAS CITY	LOS ANGELES
ATLANTA	---	2,000	1,500	---	400	---	---	---	---	---	---	---	---	---	250	---
BALTIMORE	800	---	1,200	---	6,000	2,100	---	---	1,100	---	---	---	---	---	250	---
BOSTON	725	425	---	---	8,000	5,200	---	---	1,250	---	---	---	---	---	---	---
BUFFALO	---	---	840	---	42,000	---	---	---	17,300	9,300	---	2,460	---	2,300	---	---
CHICAGO	800	8,250	7,360	31,700	---	32,120	3,000	7,500	30,500	49,250	2,500	62,150	3,250	52,100	12,100	16,540
CLEVELAND	---	---	2,350	3,570	27,692	---	---	1,540	12,392	4,590	---	3,248	---	4,920	---	2,230
DALLAS	---	---	---	---	2,650	---	---	1,580	3,900	---	2,700	---	3,500	---	7,000	2,100
DENVER	---	---	---	---	7,000	740	1,850	---	---	---	2,200	---	---	---	---	4,200
DETROIT	---	---	1,500	17,000	32,000	15,000	4,000	---	---	21,000	---	18,500	3,100	1,750	4,300	---
ELKHART	---	---	---	13,500	44,000	6,125	---	---	19,500	---	---	23,000	---	2,100	---	---
FRESNO	---	---	---	---	3,250	---	3,200	3,100	---	---	---	---	---	---	---	6,850
GIBSON	---	---	---	4,500	57,690	7,230	---	---	21,360	18,600	---	---	---	---	---	---
HOUSTON	---	---	---	---	4,320	---	3,900	---	2,300	---	---	---	---	---	550	---
INDIANAPOLIS	---	---	---	1,800	46,800	4,500	---	---	7,400	2,300	---	---	---	---	---	---
KANSAS CITY	---	---	---	---	15,640	---	9,210	---	2,900	---	---	---	---	---	---	---
LOS ANGELES	---	---	---	---	18,920	2,100	3,900	5,240	---	---	5,240	---	---	---	---	---

Figure 1. Crisscross load study

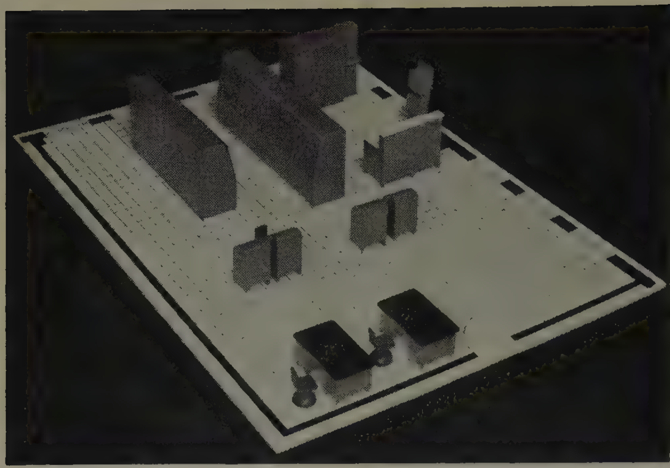

Figure 2. Typical layout of a small switching center

However, in the interest of space economies, I shall describe only the operation of Western Union's most moderate patron switching system called plan 51.

The headpiece shows an assembly of operating cabinets of a plan 51 unit. Each operating cabinet consists of an upper and lower position. In other words, two circuits are terminated in each cabinet. Each circuit termination is made in a printer-perforator which prepares the tape and is controlled by electric signals on the line. Each position also has a tape transmitter which can be associated with any of the sending circuits in the center through a push button panel situated just above the tape transmitter. The tape flow from the printer-perforator through the tape transmitter is continuous. In ordinary operation the tape is not removed from the tape transmitter nor is any tearing of the tape involved.

Figure 5 is a close-up of one of the operating positions with covers removed, showing the receiving printer-perforator at the right and its associated tape transmitter at the left with the push button panel just above the transmitter. To the left of the tape transmitter a chute is provided for the sent tape which flows into a storage bin in the table for ready access in case of question. The usual tight tape stop equipment is provided as well as tape accumulators which have been found desirable when lengthy messages are being relayed.

Figure 6 discloses a close-up of the switching panel. It will be noted that each station designation has a small lamp and a push button associated with it and that in a section to the right of the panel a group of lamps and buttons are located. Particular attention is directed to the lamps marked "message waiting," "stand-by," and "operate."

If, for example, this switching panel is at the Indianapolis, Ind., receiving position in the Chicago switching center and a message has been received and is in the tape transmitter awaiting switching, the message waiting lamp shown in the upper right hand corner of the panel will be glowing thus indicating to the operator the need of a switching operation at this turret. The operator reading the first four characters on the tape finds that the message is destined to Detroit, Mich. The button marked "Detroit" is pressed and the lamp is caused to glow above the pressed button. At this time the stand by lamp is lighted and the message waiting lamp extinguished.

This indicates that a request for the Detroit circuit has been made. When noting the destination of the message the operator also noted that the message was received as, for example, message number 69 from Indianapolis. Each position is provided with a message number sheet (see headpiece) with consecutive numbers in blocks of 100 printed thereon. The operator crosses off the number 69 on the associated Indianapolis sheet and in this manner concludes all work necessary in the switching of the message. As soon as the Detroit circuit becomes available, the stand by lamp on the panel goes out and the operate lamp glows. This indicates that the Detroit circuit now has been seized and the message is being transmitted.

Associated with each circuit is an automatic message numbering machine, the function of which is to transmit to the line a group of letters identifying the center at which the switch is made and the station to which the message is being routed, as well as to apply a consecutive channel number prior to the transmission of such message. Simultaneous with the line seizure a "diary teleprinter" is connected to the circuit. The function of this teleprinter is to copy the complete top or address line of every message transmitted through the office. Thus, now that the Detroit circuit is seized, the diary teleprinter is connected to that circuit and the numbering machine, which is associated with the Detroit circuit, transmits the switching center code letter, the station code letter, and the next consecutive message

Destination relay office
Office of Origin
Daily consecutive identifying message number
Date
Name of addressee
Street address and destination

WUCHGO NWYK 57 6 RELAY (CR LF)
NIXON BROS (CR LF)
230 LEE ST GRANDRAPIDS MICH (CR 2LF)

TRACING SHIPMENT WITH BOSTON FREIGHT WILL EXPEDITE (CR 2LF)

MAGEE FRT AGT PC&O NEWYORK (CR 10LF) (2CR 2LTRS)

Signature and originating office
Line feeds for message spacing
Switching Control signal

Figure 3. Typical standard form for on line or system messages

identifying number for this channel. As soon as this is done the message body will be transmitted to Detroit. The diary teleprinter, having copied the transmission from the numbering machine and the first line of the message, which includes the destination, office of origin and origin identifying message number, and the date, will be cut off and then will be ready for another connection upon receipt of another circuit request. In this manner, the diary teleprinter maintains a complete record of every message flowing through the office so that ready reference may be made thereto and any message quickly located when the necessity for doing so arises.

Figure 7 shows an example of a diary printer record of a group of messages switched from a center with the call letter *Z* (Chicago). The first line of the record tells that on the 12th day of the current month a message originating in Chicago at the *A* position as message number 200 (*A200*) destined for Kansas City, Kans., (*KSCY*) was sent there over the Kansas City circuit (*ZK*) as message 62 on that circuit (*062*). The fourth line of Figure 7 tells us that message 69 received from Indianapolis was sent to Detroit on the Detroit circuit (*ZD*) as message 281 (*281*).

In discussing the message form, attention was directed to a switching control signal of two carriage returns, two letters, with which every message or unit of work must be terminated in accordance with this routine. As these characters pass through the tape transmitter the mechanism operates to break the connection to the circuit thus extinguishing all lamps and restoring the circuit to a normal unoperated condition.

In the event that the operator presses the wrong button, and the operate light indicating actual circuit seizure has not yet glowed, the request for the circuit may be cancelled by pressing the message disconnect button (Figure 6) after which the proper circuit button may be pressed for correct routing. If, however, the operate light is glowing indicating the circuit has been seized, pressure of the message disconnect button will be ineffective and the message should be treated on a misroute basis.

In the event that another message follows the one which just has been switched, the message waiting lamp again is caused to glow as soon as the first letter of the destination address reaches the pins of the tape transmitter. The glowing of the message waiting lamp calls the operator's attention to the fact that another switching operation at this position is called for. Suppose, however, that the message just switched has none immediately following it. It then becomes necessary to provide a loop of tape between the printer-perforator and the tape transmitter so that the entire message may be passed through the tape transmitter without delay. Because no messages follow, a tight tape condition will be experienced during the transmission of the body of the message. However, the message having been completed as far as reception is concerned, the letter combination of the message termination will be resting in the printer-perforator and idle tape automatically will be fed out of the printer-perforator.

This feed out is of measured length and is just long enough to allow the complete message to pass through the tape transmitter. In the event that the automatic feed out is in

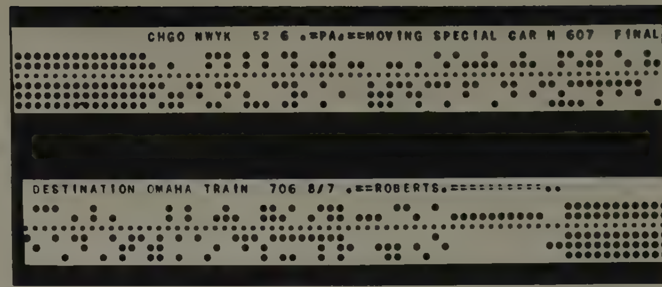

Figure 4. A message on the printer-perforator tape

operation and the recording of another message is started the automatic feed out becomes instantly inoperative at the reception of the first signal of the new message.

In some types of business it is the practice to send identical advices to a number of destinations. This requires the sending of the same message to several addresses. Where this type of traffic is heavy it becomes advisable to incorporate a master sending position in the switching center. Suppose the message shown in Figure 8 is received. The operator noting this to be a multiple address message by reason of the letters *MX* on the first line of the address and the multiple station calls on the second line, presses the button connected to the master sending position where the message is received on a printer-perforator. Associated with this position is a special master switching panel (Figure 9). As soon as the intelligence in the tape engages the pins of the tape transmitter the message waiting lamp is lighted. If switching is not started in 20 seconds the message waiting light flashes indicating operator laxity. The master send operator reading the many destinations of the message, sets up the pattern by pressing the buttons involved. At each selection of a button the lamp above the button glows, steadily if the circuit is idle and flashing if the circuit is busy. If a circuit is closed out (not in operation) a buzzer will sound when the associated button is pressed and the lamp will not glow in which case a "storage position" button is pressed and the message stored for resending to the closed station later.

After the pattern is set up and checked, a start button

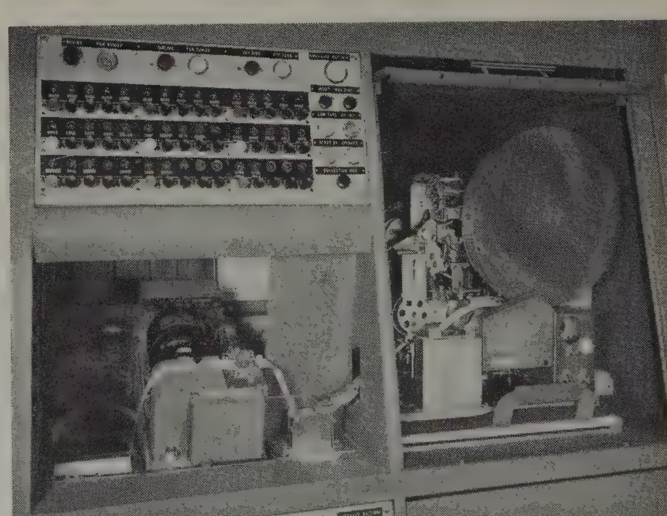

Figure 5. Operating position of plan 51 unit

Figure 6. Switching panel

situated at the right of the panel is pressed initiating actual collection of and sending to the circuits involved. As a circuit is seized the next message channel number is sent and the circuit held, until all circuits in the pattern have been seized and channel numbers sent, after which the body of the message is transmitted to all stations involved.

In the event one circuit is busy for more than 20 seconds after complete selection of all other circuits has been made, a buzzer sounds to call attention to the offending circuit so that supervisory action can be taken.

A master sending monitor teleprinter is provided and is arranged to record:

1. Calls of stations to which the multiple address message is sent.
2. Circuit message numbers under which the master message was transmitted.
3. The complete message.

Thus a complete check of correct routing can be made by the supervisor.

At the end of the operating aisle is a cabinet quite dissimilar from those just examined. This cabinet, Figure 10, is a supervisory unit and is equipped with a keyboard perforator for sending supervisory notes. Directly above the keyboard perforator are a number of switches and lights. These switches are associated with the circuits operating into and out of the center, each switch and light representing one station. With the switches turned to the normal position, and the circuits operating normally, no lamps will be lighted. Suppose that some of the offices connected to the center are closed while others remain open. In this case, the supervisor or operator must be sure that no messages will be sent to these offices after closing time. This is done by turning the panel switch, associated with the office to be closed, to the right. This causes the associated lamp to glow and also prevents the possibility of connection to that particular circuit from any of the switching panels. Should an operator, under these conditions, have a message for a closed out office, she presses a button marked "spillover" which will connect the transmitter to a printer-perforator in the switching center. The message will be received on this printer-perforator and stored in a tape tank until the time of opening of the office involved. In the event that the operator attempts to switch to a closed office, no connection will be made to the circuit. Upon pressure of the button associated with this office, the stand-by lamp, instead of glowing steadily, will flash, indicating abnormal condition.

Messages submitted to the center for transmission over the system are prepared for switching from a standard teleprinter keyboard. This teleprinter is connected to a receiving printer-perforator in the center, the tape from which is switched in exactly the same manner as the tape from any other receiving printer-perforator in the system.

Messages addressed for delivery from the switching center are switched to a local receiving teleprinter in the center, which types the message in exactly the same manner as at any distant station connected to the system.

Messages received for "off line" delivery are switched to the Western Union telegraph office in the same manner as any other switch.

The circuit arrangements are such that if a circuit goes open or grounded during the

```
ZK062KSCY CHGO A200 12
ZL122LOSA CHGO B98 12
ZN084NWYK LOSA 86 12
ZD281DETR INDP 69 12
ZA220CHGO NWYK 52 12
ZW118WUCHGO NWYK 57 12 RELAY
```

Figure 7. Diary printer record

```
MX CGO B 185 16
NYK BSN ATL LOS STL CGS
STORE MANAGERS
ADVISE STOCK OF AUTO TIRES 6.50X16 ALL GRADES.TUBES
ALL GRADES AND SIZES. SPARK PLUGS STANDARD BRANDS.

             SUPT STORES CGO..
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Figure 8. Typical multiple address message

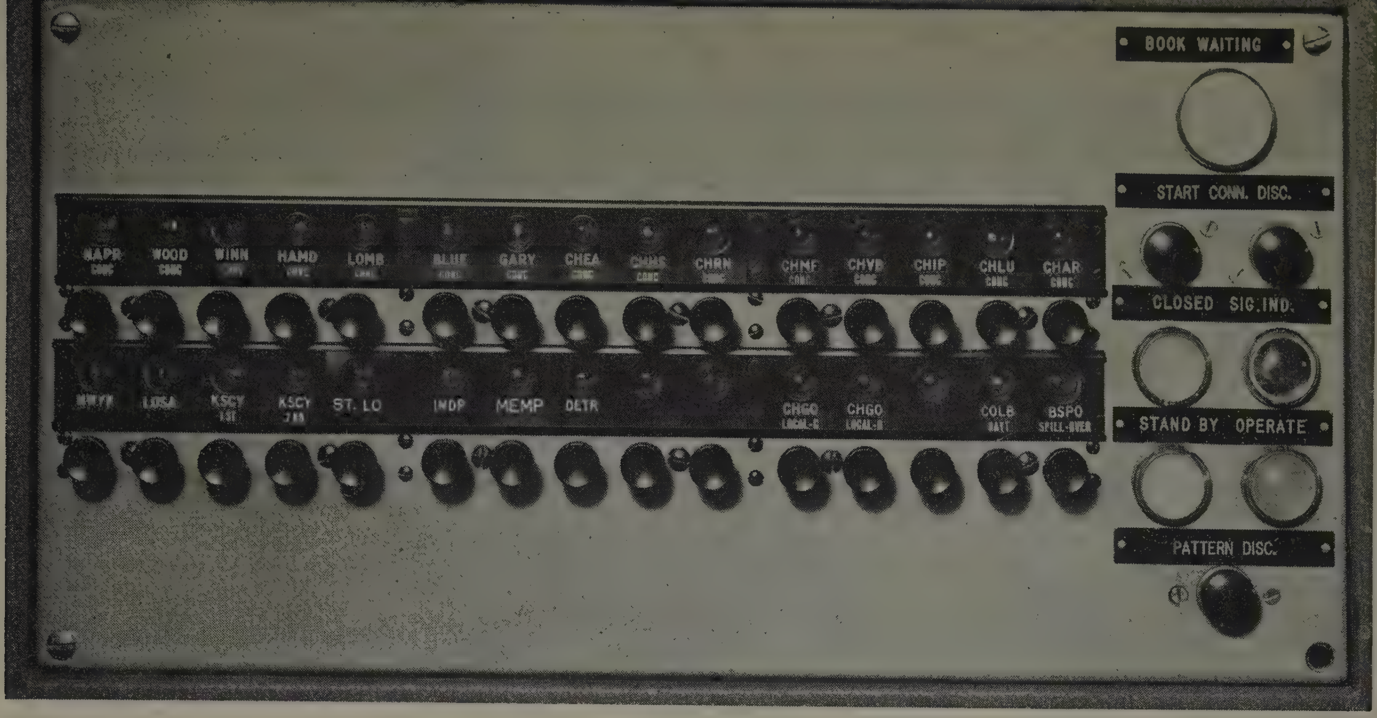

Figure 9. Master switching panel

transmission of a message the tape transmitter immediately will stop and the operate lamp will flash intermittently thereby indicating the need for investigation of an abnormal line condition.

Plan 51 apparatus is designed on a clip-connection basis so that all apparatus including switching panels, printer-perforators, tape transmitters, relay banks can be removed readily and substitutions made.

Ease of addition or removal of operating positions is also an important factor and to this end, the design is carried to the point where, by means of corded plugs, cabinets can be removed or added readily. Figure 11 reveals the rear of one of these cabinets with the cords and plugs in place.

It also shows rotary switches and relay banks which are employed in connecting the associated distributor transmitters to the selected circuits and in the control of such funtions as stopping the distributor transmitter at the end of a message and automatic tape feeding of the printer-perforator.

A central control cabinet which is the heart of the installation is shown in Figure 12. Here on the two top shelves are several automatic message numbering machines, one for each station served by the message switching center. Below, are distributors, and to the right, an allotter switch. These instruments play a part in the pickup and seizure of the circuits through the push button panels, as well as the transmission of consecutive numbers and the operation of the diary teleprinter.

Complete testing equipment is provided with each plan 51 center and is shown in Figure 13. Facilities for testing relay banks, printer-perforators, distributor transmitters, and numbering machines, as well as teleprinters, are available. Figure 13 also shows the rectifier equipment provided for furnishing the direct current for the unit.

AUTOMATIC NUMBERING MACHINE

In discussing the operation of the switching centers reference has been made to an automatic numbering machine which is employed primarily in sending automatic consecutive channel numbers upon seizure of a transmitting circuit. Inasmuch as this unit is rather novel in its operation and construction, it may be of interest to discuss it briefly. Figure 14 shows a 3-digit automatic numbering machine. This machine employs four rotating drums on which contact operating studs are placed. The primary or transmitting drum has ten positions and is so arranged that the signal combinations from this element may be varied by rearrangement of the studs. The other three drums all have combinations of studs representing the numbers zero to nine. A normal setup of the studs on the transmitting drum might be letters, letters, letters, *Z*, *B*, figures, digit, digit, digit, letters. The *Z* representing the switching center

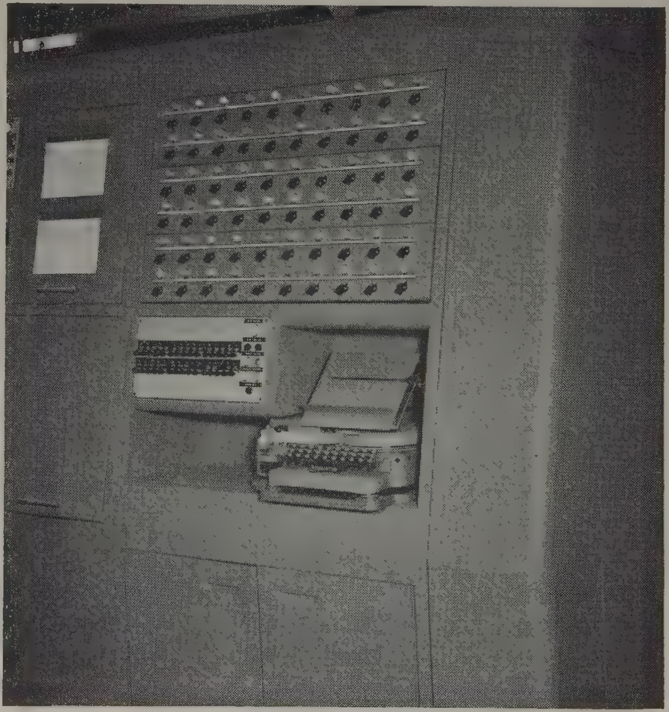

Figure 10. Supervisory unit

Figure 11 (left). Rear of cabinet

Figure 12 (right). Central control cabinet

call letter and the *B* representing the station to which the message is being sent, and, of course, the number (digit, digit, digit) representing the consecutive channel identifying number. In many instances, the numbering machine is employed for automatically selecting stations on way circuits in addition to sending the message numbers. If a way circuit is connected to a switching center and has, let us say, three stations on it, the line will be equipped with three numbering machines, one for each station. As the required numbering machine is activated, it transmits, preceding the station letters (*ZB* above) and in place of the three letter combinations, the selector signal for the station involved. With this arrangement, the operator need not know that she is switching to a way station, as the operation of the selecting function is automatic.

Other equipment used in this method of switching is more or less standard or at least follows accepted design so no further description will be made of the units employed.

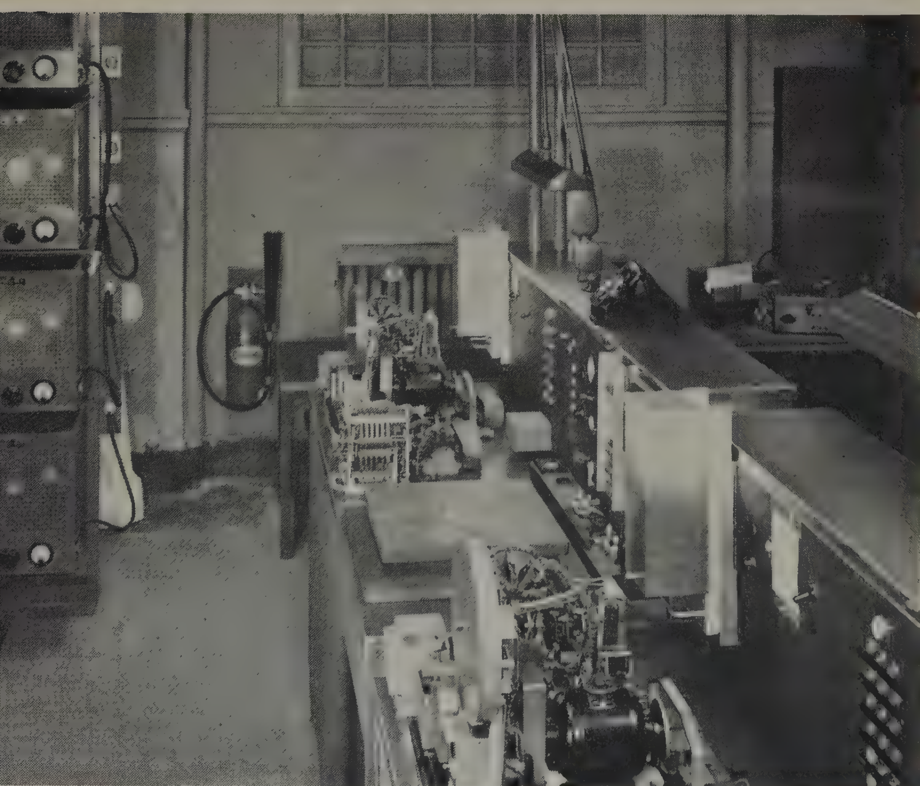

Figure 13. Testing equipment provided with each center and rectifier unit

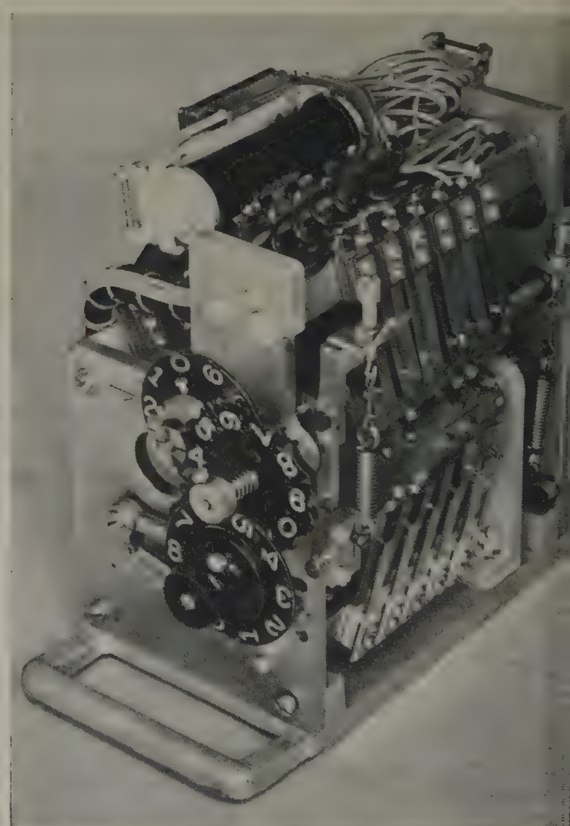

Figure 14. Three-digit automatic numbering machine

Conductors—Types, Availability, and Use

AN AIEE COMMITTEE REPORT

MANY ELECTRIC CIRCUITS at all voltages have been overloaded at one time or another during the war. This trend toward operating transmission circuits beyond their economic rating from necessity is being extended seriously into the postwar period. At the same time all conductor materials have been in short supply.

Lately, aluminum in various forms is being produced at such a rate that it is becoming more and more competitive with copper in practically all types of electrical installations. Individual requests for information have been made to engineers who have had more experience than others with use of all-aluminum conductors, and with bimetallic conductors wherein steel or other materials are used to permit of greater mechanical loads per conductor. Some of the national associations have asked for reviews of experience with aluminum conductors throughout the United States.

Reconductoring is one of the more available methods of controlling losses in overloaded circuits. Experience indicates that all-aluminum conductors, when erected strictly in accordance with the recommendations of the manufacturers and under the direction of their supervisors, will operate indefinitely, that is, over 30 to 40 years, and after that time, if it is desirable, they can be re-erected if carefully reeled up and inspected. It is advisable to give more attention to the oxide films which build up on aluminum conductors at jointing surfaces than usually is given for copper.

Steel-reinforced conductors are generally competitive as to mechanical and electrical characteristics, and as to age, with copper conductors. For instance, copper and ACSR (aluminum cable steel reinforced) conductors have been operating at 132,000 volts on either side of double-circuit steel structures with practically the same results over approximately 1,500 mile-years for each circuit.

Some interesting conductor designs are shown in Figure 1. The three proposals indicated in part *A* are for large single conductors of 2-inch diameter or less. These are being tested at the Tidd experimental station. The upper and lower conductors are typical of expanded conductors used for transmission and bus work at 230 kv. The center unit is an expanded aluminum conductor with steel reinforcement and stranded paper filler cords. The three cross sections indicated in *B* include types which were proposed for 230 kv, but expanded to a 2-inch diameter. They neither are authorized nor sponsored. Production and handling characteristics and problems have not been investigated. The center unit incorporates individual aluminum wires, having the same lay, with each layer of paper cords and is alternative to the ACSR conductor used at the Tidd station. This section seems to have considerable merit for those desiring to authorize maximum useful conductivity in conductors having 2-inch diameters. Conductors shown in *C* have been made experimentally in Europe. The upper unit is a typical "Preiswerk" section. Installation with dead-ending and splicing equipment was made on this continent several years ago. It was difficult to erect and maintain. The center unit is adaptable to either or both the special features above and below it. The lower unit indicates alternate strands of aluminum and, say, ductile stainless steel for reinforcement.

More conductivity, higher voltages, lower costs, and less expensive conductor materials are indicated as a trend in the requirements of consumers, while service security and more kilowatt-hours delivered will command the attention of producers and administrators.

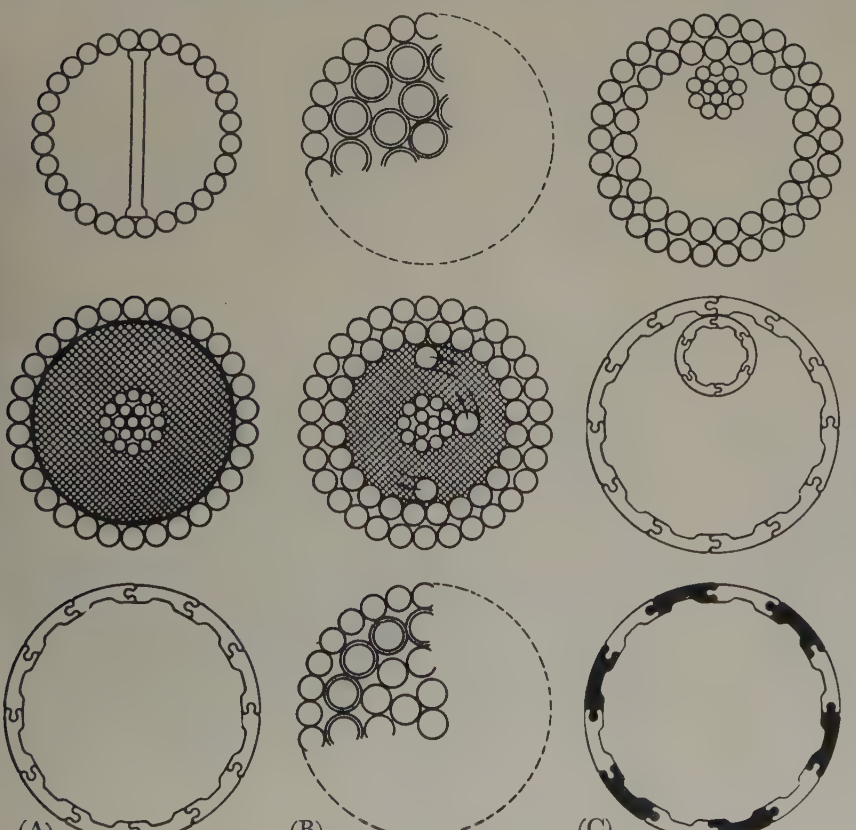

Figure 1. Some proposed conductor designs

Those shown in A are for conductors up to 2-inch diameter; those in B are 2-inch conductors; and in C are shown conductor types that have been made experimentally in Europe

Digest of paper **48-139**, "Conductors—Types, Availability, and Use," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

This report was prepared by the AIEE subcommittee on towers, poles, and conductors (chairman, **A. E. Davison**) under the supervision of **C. Wagner** who is chairman of the AIEE transmission and distribution committee.

The Rotary Automatic Telephone System

WILLIAM HATTON

STARTING WITH a few small offices more than 35 years ago, the use of the rotary automatic telephone system of the power-driven type has extended to practically all parts of the world. Today it is standard equipment for many of the leading administrations and telephone operating companies and now is being introduced for the first time into two of the major independent telephone systems in the United States. The initial installations in the United States involve the conversion from manual to automatic operation of a 15,000-line central office at Rochester, N. Y., in July 1948, and the main central office of about the same size at Lexington, Ky.

In a power-driven system, such as the rotary automatic telephone system, the switches are mounted on frameworks which also are equipped with constantly rotating shafts and arranged such that each individual switch drive may be connected or disconnected by means of electric clutches. The operation of these clutches is controlled indirectly through registers by the impulses of the calling dial, that is, the dial impulses are received in a register which properly translates them to control the operation and release of the clutches of the individual switches required for selecting the wanted subscriber's line. A finder switch with drive is shown in Figure 1. A group selector consisting of ten circuit levels each comprising three rows of terminals is shown in Figure 2.

Among the numerous inherent advantages of power-driven systems, the following may be mentioned as most important:

1. The power drive permits the use of switches of simple construction which can be made rugged enough to withstand the wear imposed by the heaviest telephone traffic over a period of many years. This, of course, results in reducing to a minimum the annual charges for maintenance and depreciation and also brings to a minimum the service reactions due to central office equipment.

2. The use of power drive and the fact that the switches are not under direct control of the impulses of the calling dial permits the smooth operation of switches having large capacities. This allows the use of large groups of trunks between successive switches in the selecting train, resulting in a very considerable reduction in the number of trunks and switches required.

3. Because the movement of switches is not directly dependent upon the impulses of the calling dial, a great and valuable increase in flexibility is obtained in the routing of calls through a network and in the numbering schemes that can be used for an exchange area, a district, or a large territory.

Many of the major improvements in automatic telephony in recent years may be attributed to the power-driven system by the development and perfection of the more complicated things in machine switching. It introduced office prefix translation, flexible trunking, call indicator working to manual positions, high speed direct trunking from manual to automatic, toll dialing, national multiple metering as in Switzerland, national automatic ticketing as in Belgium, means to restrict the maintenance of the exchange to the normal day hours, and the improvement and perfection of the equipment and circuits so as to permit maximum nonattended periods.

Digest of paper 48-140, "The Rotary Automatic Telephone System," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

William Hatton is with the International Telephone and Telegraph Corporation, New York, N. Y.

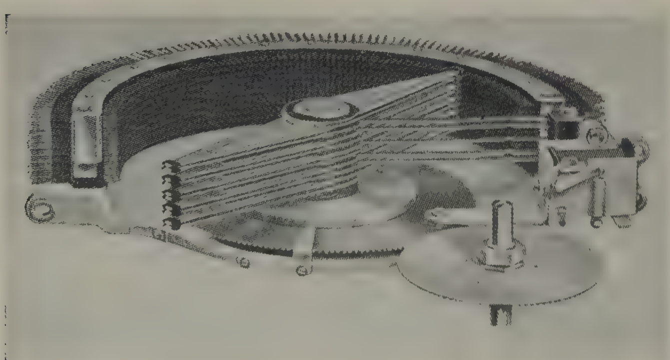

Figure 1. A complete finder switch with drive

The signal to start the switch may come from any one of the circuits connected to the 200 terminals. The brushes move over the terminal banks until the calling terminal is reached and then the signal stops the rotation of the brushes. Rotation is in a single direction and one end of the double-ended brushes makes contact when the other leaves the bank

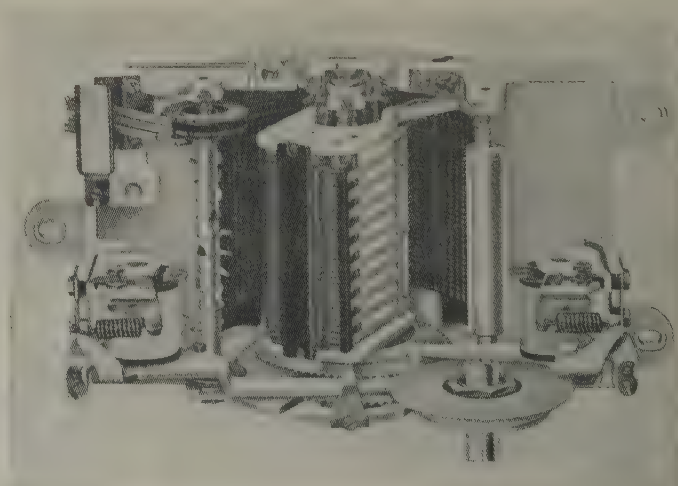

Figure 2. A group selector consisting of ten circuit levels each comprising three rows of terminals

A group of three contacts on one level of the rotating brush assembly may be tripped to make contact with the desired terminals

Trends in Electronic Engineering

DONALD G. FINK
MEMBER AIEE

The field of electronics may be divided into three segments: entertainment and education, communications, and industrial applications. Developments since the war in each of these areas of activity have been notable, but of particular interest is the rapid progress which has been made in the largest division of the field, broadcasting, and emphasis is placed on trends in frequency modulation and television.

THE FIELD of electronic engineering has emerged in the postwar world as the most active branch of electrical science. Based fundamentally on the conduction of electricity in gases or in vacuum, electronics has come to include many branches of technology formerly classed as separate entities. As an introduction to this review of recent progress in electronic engineering, therefore, it is well to outline the field.

Electronic engineering divides, on technological as well as economic grounds, into three well-defined areas of activity:

1. Entertainment and education.
2. Communications.
3. Industrial applications.

The first classification includes broadcasting by amplitude modulation or frequency modulation, and comprises services for sound (sound broadcasting, motion pictures, phonograph recording, and public address) as well as visual transmissions (facsimile and television).

The second classification, closely related to the first, is concerned with the transmission of information other than for public consumption and includes the fields of telegraphy and telephony, between fixed or mobile stations, by wire or radio.

The third classification, the industrial applications of electronics, includes all parts of the field not related to broadcasting or communications. This field may be defined as the application of electronics in which the essential aspect is the control, guidance, or supervision of a process, or the manipulation or measurement of physical and mathematical quantities to perform an industrial process or commercial service.

As industrial electronics is by far the most diverse aspect of electronic engineering, it requires a further breakdown. The first division is the guidance of commercial transportation, that is, the use of radio and electronic aids to navigation, traffic control, landing and docking, anticollision, and other safety services. This field has been classified loosely as an aspect of communications technology, as the techniques used in the two fields are similar. But in line with the definitions given, radar, loran, and other navigational systems are clearly industrial applications.

The second division is the production and control of heat, such as control of resistance welding and the production of heat in conductors or dielectrics by immersion in high-frequency fields.

The third division includes the supervision of processes and protection against hazards. Intrusions alarms and monitors, and protection of operators against hazards presented by machinery are included.

The fourth division comprises continuous process controls. Such continuous processes as printing, wrapping, weaving, plating, rolling, perforating, finishing, sorting, and grading may be controlled or monitored by electronic devices sensitive to some physical quantity, such as weight, thickness, temperature, humidity, angle, position, balance, pressure, color, reflectance, or resistance.

The fifth application involves the manipulation of mathematical quantities, not for control purposes, but for computation. This group includes the many new forms of electronic computers of the digital and analogue types.

The sixth and final division is the large field of electronic measurements, not related to control. Many physical measurements, particularly those involving the perception of minute amounts of radiant or corpuscular energy, cannot be carried out except by photographic or electronic means. The electronic techniques have a considerable advantage over the photographic ones in respect to convenience.

With this brief outline of the field before us, we can proceed to a detailed examination of recent progress in each of the divisions just described.

TRENDS IN BROADCASTING

The field of broadcasting commands first attention because it represents by far the largest division of the field from the standpoint of economic investment and employment of technical personnel. Largely as a result of the universal presence of radio receivers in American homes there are, in North America, more electron tubes than there are people.

Considering first conventional sound broadcasting by amplitude modulation, it must be reported that few outstanding technical improvements have occurred in recent years. The principal recent trend in the United States has been along social and economic lines, namely, the very great increase in the number of stations occupying the already overcongested broadcast channels. In December 1945, there were 1,056 amplitude modulation broadcast stations in the United States and its possessions. Two years later,

Full text of paper **48-128**, "Trends in Electronic Engineering," recommended by the AIEE electronics committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948; scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Donald G. Fink is editor, *Electronics*, McGraw-Hill Publishing Company, New York, N. Y.

there were 1,961 such stations, an increase of nearly 1,000 stations in 24 months. These new stations were authorized by the Federal Communications Commission following a decision of the United States Supreme Court which, in effect, required the commission to issue licenses without considering the economic status of existing stations. As a result, interference among stations, particularly during nighttime hours, has increased, and this has focussed attention on directional antennas. Many stations have erected 2- and 3-element arrays to reduce the signal strength in direction of other stations occupying the same channel. Otherwise there is little change in the service to note. Network telephone-line connections continue, for the most part, to limit audio fidelity at 5,000 cycles per second. Similarly, little change has occurred in the design of broadcast receivers, except that higher quality components and better audio systems are used in expensive models, largely because these receivers have facilities for frequency modulation.

In contrast, the progress of frequency modulation broadcasting in the United States during recent years has been marked. Frequency modulation station assignments are made in the band from 88 to 108 megacycles, with a few assignments still active on the older band, 44 to 50 megacycles. Stations in the latter region, notably station *W2XMN* in Alpine, N. J., operated by the inventor of wideband frequency modulation, Doctor E. H. Armstrong, have served as key stations in radio-relay frequency modulation networks which pemit high-quality network connections without telephone lines. Telephone lines having an 8,000-cycles per second upper cutoff have also been used in frequency modulation networks, and early this year plans were underway for the use of lines with a 15,000-cycles per second cutoff.

At the end of 1947 there were 376 frequency modulation stations regularly on the air, and construction permits had been issued for 629 additional stations. By the end of 1948 it was predicted that there would be nearly 1,000 frequency modulation stations operating, or about the same as the number of amplitude modulation stations operating in 1945.

Approximately one million frequency modulation receivers were produced in 1947, which represented about one out of every 17 sets manufactured during that year. This represented a sixfold increase in production over the previous year. Frequency modulation receivers continue to be expensive, few table models selling at under 50 dollars. One step in the direction of cheaper frequency modulation sets is a new one-tube frequency modulation circuit combining the functions of superregeneration and the superheterodyne. While the performance of this simple circuit leaves much to be desired, it permits a combined amplitude modulation–frequency modulation table model set to be marketed for $30.

More rapid popularization of the frequency modulation service has been prevented by the action of Caesar Petrillo, head of the American Federation of Musicians, who refused to allow programs of the standard amplitude modulation broadcast stations to be broadcast simultaneously over frequency modulation stations without payment of double fees to the musicians. Consequently programs on frequency modulation stations consisted almost exculsively of phonograph records, and the listening audience was small. The Petrillo edict was withdrawn on February 1, 1948, and a steady increase in the frequency modulation audience since has occurred.

The power levels of frequency modulation stations, in the 88-to-108-megacycle band, range from 250 watts to 10 kw. Several 50-kw transmitters are in operation in the lower band, 44–50 megacycles. High-gain antennas, which compress the signal in the horizontal direction, are usual, producing an increase in effective radiated power of from two to six times. The effective range of a high-power transmitter with a high gain antenna is nearly 100 miles, if the receiver was located favorably, although reception at ten miles may be unsatisfactory if large obstructions intervene.

Perhaps the most rapid progress of all, in the field of broadcasting, is that made by television. Permission to operate television stations commercially first was granted by the FCC in July 1941, but construction of new stations was halted immediately by the war. At the war's end, seven stations were in operation. At the end of 1947, 16 stations were on the air in 11 cities. Construction permits for 56 additional stations in 32 additional cities had been granted, and applications for 84 stations were pending before the FCC. In 1946, some 6,500 television receivers were manufactured; in 1947 this production has risen to 178,000. One large manufacturer reported that nearly half of the income derived from manufacturing radio receivers was accounted for by television sets.

The first television network took form along the Atlantic seaboard in 1947, connecting ten stations in Washington, Baltimore, Philadelphia, New York, and Schenectady. The coaxial cable, with a band width of 2.7 megacycles serves from Washington to New York. Microwave radio relays, operating at frequencies in the thousands of megacycles, connect New York, Philadelphia, and Boston. During a demonstration of the microwave relay system between New York and Boston (220 miles long), a television program was repeated back and forth over the system four times, or a distance equal to that from New York to Chicago, without visible degradation of the picture quality. Construction of a similar microwave relay between New York and Chicago is underway.

Television receivers range in price from $150 to $2,500, and produce pictures ranging in size from 4 by 6 inches to 15 by 20 inches, for home use. The larger size pictures are produced by a Schmidt projection system which enlarges the image from a small (4- or 5-inch) cathode-ray tube. Directive viewing screens for projection receivers enhance the image brightness by a factor of ten times, and permit satisfactory viewing in a sun-lit room. Of the 13 channels allocated by the FCC, no more than seven are assigned to any one locality. All commercial receivers have facilities for receiving any of the seven local stations, and many receivers provide tuning for all 13 channels. Picture brightness (in the highlights of the scene) of 50 foot-lamberts is achieved, with a contrast range as high as 100-to-1. The detail of the images varies from 100,000 to 150,000 picture elements per frame, depending on the excellence of the television camera in use and the effective bandwidths (three to

four megacycles) employed by the receiver. The higher figure approximates closely the detail available from 16-millimeter motion pictures. The images are sent in a 525-line scanning pattern at a rate of 30 complete pictures per second.

Television for theaters is under active development. Images of six by eight feet were demonstrated at the International Telecommunications Conference in Atlantic City in the summer of 1947.

Among the most important of the recent technical developments in television is the image orthicon camera tube. This tube, which combines the properties of photoelectric emission, charge storage, and electron multiplication, is the most sensitive continuously registering light-sensitive device known to science. This camera will register an image under the illumination of a single tallow candle six feet from the subject. Such dim light will not actuate photographic film, when the same exposure (about 1/30th second) is used. In fact, the effective photographic speed of the image orthicon camera, for threshold values, is about Weston 2,000, compared with Weston 200 for the fastest photographic film.

The other form of visual broadcasting, facsimile, is ready for use, but has not been introduced to the public to any extent. Standards of transmission have been agreed upon by the industry and presented to the FCC, and experimental transmissions have occurred on a number of frequency modulation broadcast stations (being transmitted by multiplex methods simultaneously with the frequency modulation sound program) but facsimile equipment for the home is not as yet available and it appears that further co-ordinated effort by receiver manufacturers and broadcasters is required before the service becomes established. Facsimile service for communication purposes, particularly the transmission of news pictures and business documents, is well established at present.

SOUND REPRODUCTION

Widespread use of electronic techniques is made in entertainment and educational pursuits other than broadcasting. The sound aspect of motion pictures is a typical example. Since the advent of ultraviolet recording and the perfection of light-valve characteristics, little technical progress has been reported in this field. But in other types of sound recording, very rapid strides have been taken in recent years. In conventional disk recording the employment of better materials (particularly vinylite plastics) for pressings has resulted in a marked improvement of the tonal range, as high as 14,000 cycles in current British records, and also a great reduction in the background noise which is inherent in the records.

An important and technically interesting improvement in the reproduction of disk records is the dynamic noise suppressor. In the form of suppressor developed by H. H. Scott, the tonal range of the reproduction is varied automatically and continuously, in response to changes in the volume of the recorded sound. Thus when the volume is low, the frequency range is restricted by an electronically controlled wave filter. This restriction removes noise, but does so only when the volume is low and the noise would be prominent if not removed. Since the tonal range to which the ear responds is naturally restricted at low volume levels, the tonal restriction is not perceived to any great degree. During loud passages of the music, the full tonal range is reproduced, as is required by the ear at high volumes, but the noise then is masked by the music and is not perceived. Such suppressors produce an amazing improvement in apparent signal-to-noise ratio on musical recordings, without audible degradation of the tone quality.

Another area of high activity in sound reproduction is the development of wire and tape recorders. The early forms of wire recorder had rather restricted tonal range, but reproduction faithful to 8,000 cycles has been achieved on wire, and up to 13,000 cycles per second in tape recorders. The latter, following German practice, employ a finely-divided iron-powder emulsion deposited on a cellulose tape base.

TRENDS IN ELECTRONIC COMMUNICATION

Turning now to the field of communication by telegraphy, telephony, television, and facsimile, we encounter first an important addition to the theory of communication which has important practical implications in trunk-line telephony by radio relay. The new theory relates to the bandwidths required to transmit a given amount of information in a given amount of time. The classical statement of this relationship, the Hartley law, states that the minimum bandwidth, required in a communications channel to transmit information at a given rate, is equal to the spectrum occupied by the information itself. Thus, the band of frequencies occupied in commercial telephony extends from 250 to 2,750 cycles per second. An ideal single-sideband system would require a frequency band at least 2,250 cycles per second wide to transmit this signal. If transmitted by double-sideband amplitude modulation, the band required is at least 4,500 cycles per second, and if wideband frequency modulation with a modulation index of 5 is used, the required bandwidth is at least 22,500 cycles per second.

The new theory takes into account the noise present in the transmission channel and states that the minimum bandwidth required is proportional to the quantity $\log (1+S/N)$ where S/N is the signal-to-noise power ratio in the transmission medium.

This law, derived independently by workers in the Bell Telephone Laboratories, Massachusetts Institute of Technology, and California Institute of Technology, has rather startling implications. The most important of these is that, if the signal-to-noise ratio in the transmission path may be made arbitrarily large (by employing an unlimited amount of power at the transmitter), the bandwidth required for full and accurate reproduction of the information may be made arbitrarily small. Thus, if resources are available to keep the transmitter power sufficiently high at each repeater point in a telephony, telegraphy, or television system, the bandwidth of the transmission system may be reduced below the extent occupied by the spectrum of the original intelligence. For example, a television signal, extending from 30 to 4,000,000 cycles per second as produced by the television camera, can be sent over a coaxial cable or radio relay system, having a bandwidth of only 2,000,000 cycles per

second provided the signal-to-noise ratio is kept suitably high at each repeater point.

To achieve this important economy of spectrum utilization, a particular method of modulation must be used, the only practical form of which, now known, is "pulse-code modulation," described in following. Although this system is probably not practical for broadcast use because of economic factors, it is quite possibly the optimum system of transmitting high quality telephone signals over restricted bandwidth in trunk service. Active investigation of the practical application of the new theory to telephone plant is now underway in several laboratories.

The second important trend in communication practice is employment of different modulation methods. Amplitude modulation continues to predominate in long-distance telephonic communications, and a modification of the amplitude modulation system in the form of single-sideband suppressed-carrier increasingly has been employed in long distance circuits, and most recently has been the subject of intensive activity among amateur radio telephone operators. Frequency modulation has been used widely in communications work, particularly the local services using frequencies from 30 megacycles upwards. A special form of frequency modulation system, frequency-shift keying for telegraphic circuits, has increasing vogue in long distance work. Frequency modulation even has been proposed for international (transoceanic) broadcasting, but the wide band (about 200 kc) which is required for this service probably cannot be made available even for experimental work in the overcrowded bands between 5 and 25 megacycles.

For high-frequency carrier services (300 megacycles and higher) pulse methods of modulation actively are being developed and are employed to some extent in commercial practice. The two most prominent methods of pulse modulation are pulse-time modulation and pulse-code modulation. In the first, a series of flat-topped steep-sided signals (pulses), of duration small compared with the interval between them, is set up as the basic transmission system. The intelligence to be transmitted is imposed on this sequence of pulses by varying the time of occurrence of the pulses in the sequence. This is, in effect, a phase modulation of the pulse, and the modulation may be recovered by passing the pulse sequence through a phase detector. This system has the advantage that the transmitter and receiver need not be linear, as amplitude variations above threshold are of no consequence. Moreover, the pulses may be regenerated at repeaters by trigger action. The bandwidth required for pulse time modulation is generally more extensive than for amplitude modulation or frequency modulation but, at the high carrier frequencies for which the system is intended, sufficient ether space to accommodate the wide band is currently available.

The pulse-code modulation system, previously referred to, has important advantages over pulse-time modulation in that it permits a marked reduction in bandwidth if sufficient power is used. In the pulse-code system the amplitude coordinate of the signal wave is "quantized," that is, several discrete amplitude levels are set up as index points. The wave amplitude then is sampled at regular intervals of time, and the discrete amplitude level most nearly approached at each instant of sampling is translated into a code group, consisting of pulses of equal height, spaced in accordance with a binary code. The pulse code groups are transmitted and at the receiving point, each pulse group is retranslated into the corresponding amplitude level and the original signal wave thus is recreated in quantized form. If the number of amplitude steps set up is sufficiently great, the quantized nature of the reproduction is not noticeable. A binary code of 7 characters permits $2^7=128$ levels to be used and this structure is fine enough to permit reproduction of high quality speech and music; 32 levels suffice for commercial telephonic quality. The system employs regeneration of pulses at repeaters, a process made simple by the synchronous recurrence of the code pulses.

A third trend in communications practice is the great extension of radio facilities for communication in industries outside the common-carrier telephone and telegraph companies. As of December 1947, there were 877 communication stations licensed to public utilities, 972 to operators of busses, trucks, and taxis, and several score of stations to transit utility, petroleum pipe line, highway maintenance, and geophysical prospecting companies. The majority of these communication systems employ frequency modulation in the vicinity of 30–40 megacycles and 153–160 megacycles. Amplitude modulation also is used in these bands, but no more than two per cent of the stations employ this type of transmission.

A communication service still in the developmental stage, but promising much for the future, is the Citizens Radio Service. This service was established by the FCC in 1945, in the band between 460 and 470 megacycles (three-quarter meter wave length) for the use of any citizen, not possessing technical qualifications, for private or personal communication. Equipment for this service is not yet available to the public, but is under development. When available, any citizen may obtain authorization to use approved equipment for any private purpose, merely upon application, stating that he understands and will uphold the laws affecting radio communications.

A final development in the field of communications is the great extension of the ether spectrum now available. Prior to the war the spectrum allocated by the FCC extended upward to 300 megacycles, and services were not in use above 200 megacycles. Following the war, largely as a result of the wartime development of radar, the allocated spectrum was extended by the FCC to 30,000 megacycles (one centimeter wave length). Communications system now in daily use occupy channels in the 2,000- and 4,000-megacycle range. Noteworthy in this category are the microwave relay systems, previously mentioned, for transmitting telephone and television signals from city to city in common carrier service.

INDUSTRIAL APPLICATIONS—RADIO NAVIGATION

We turn now to the industrial applications, and begin with one of the most important applications of electronic techniques to commerce, the guidance of aerial and marine transportation. Prior to the war this field was limited to the radio direction finder (direction finder loop and Adcock aerial) and the radio-range course-marking beacon. But

with the war came the active employment of several new radio aids to navigations, notably radar, hyperbolic navigation, and radar beacons. The principle of radar is by now well known. In the so-called non-co-operative type of radar, the radio wave sent is reflected by an otherwise passive object which differs from its surroundings. The direction and distance of the reflecting object are determined by directing a narrow beam toward it and timing the wave during its flight to and from the object. The resulting "echo" reflections may be displayed for visual inspection on a cathode-ray tube.

The most useful form of radar display takes the form of a maplike presentation, the center of the screen corresponding to the location of the radar, with reflecting objects shown at their proper relative distances and directions from the center. This "plan position indicator" now is employed widely as an aid to marine navigation, as it shows clearly the location and shape of coastlines and other landmarks useful in pilotage, and reveals the presence and courses of other ships. As such it serves not only as a navigation aid but as an anti-collision device. Ships equipped with such radar equipment now may run with confidence, and even may negotiate narrow rivers, in fog or darkness. Current developments may produce a radar so rapid in its perception of echoes that it can "see" objects only a few tens of feet away and thus permit docking under conditions of poor visibility.

Although similar radar devices have proved of the utmost value in military aviation, they have not been applied to any great extent to commercial air navigation. Rather, radar has been applied to aviation from the ground, notably in the "ground control approach" system (GCA). This system locates the position of an aircraft near an airport by a ground-based radar, and this information is relayed to the pilot by radiotelephone. In this manner the pilot may be guided into proper position for a landing and "talked" down to within a few feet of the ground. Air-borne radar is by no means a dead issue for commercial aviation. Recently a new lightweight radar (type *APS-42*) has been developed specifically for commercial aircraft.

A closely related system is the co-operative type of radar, in which specially-designed receiver-transmitters (radar transpondors) are set out as beacons. These receive the outgoing signal from a ship-borne or air-borne radar, and return a coded reply signal which is displayed, along with natural reflections, on the plan position indicator. In this manner the pilot of the radar-equipped vehicle can identify positively landmarks which otherwise might be unidentifiable or escape detection. One version of the radar beacon system is the distance-measuring equipment (DME) now being installed by the Civil Aeronautics Authority for commercial air line operation.

Still another specialized adaptation of the radar beacon is the shoran system, which times the reply signal from a beacon so precisely that the distance from aircraft to beacon can be measured to an accuracy of five yards, over distances of several hundred miles. Used for precision bombing during the war, shoran finds postwar application as an aerial survey instrument. Accurate charting of regions of the world by shoran has revealed errors of many miles in charts at locations (notably the Caribbean) where local disturbances in the gravitational field have prevented accurate celestial measurements of position.

Another war-developed navigational aid of continuing peacetime use is the loran system. In this system stations on islands or coastlines transmit accurately synchronized pulses, broadcast over several hundred thousand square miles of the adjacent sea. The navigator of a loran-equipped ship or aircraft observes these pulses in pairs on a cathode-ray screen in such a way that he can determine the difference in the time of arrival of the two sets of pulses at his location. As the time difference between the pulses emitted by two stations is a constant along a hyperbolic locus projected on the earth's surface, measurement of this time difference suffices to locate the navigator on one of a family of such loci, which are printed on charts of the region. Similarly measurements on a second pair of pulses from two other stations (one of which may be common to the first pair) places the navigator on another locus, intersecting the first. The point of intersection, which represents the navigator's position, can be determined to an accuracy of a few miles at distances as great as 1,500 from the stations.

At the end of the war, nearly one-third of the earth's surface was covered by loran hyperbolic co-ordinates, and a large portion of this service still is maintained by stations operated by the United States Coast Guard and agencies in other countries. Nearly 1,000 transoceanic flights now are completed each month by loran-equipped aircraft and scores of merchant vessels, in addition to all naval vessels and many military aircraft, use the system.

Many other navigational systems are under development, most of them aimed at the as-yet-unsolved problem of controlling dense air traffic in the vicinity of airports. These combine radar, radar beacons, television, and radar altimeters (automatic height finders). The latter device is a radar which measures the distance of the aircraft above ground by timing the interval of reflection of a signal sent from the airplane after it strikes the ground and returns to the aircraft.

ELECTRONIC PRODUCTION OF HEAT

Electronic heating by the immersion of substances in high-frequency fields has grown in importance very substantially in recent years. In view of this increasing use, and in view of the severe interference to communication and broadcast services which may be caused by industrial heating equipment, the FCC in 1948 set up three frequency assignments for "scientific industrial and medical" equipment. These assignments consist of bands, centered on 13.56, 27.12, and 40.68 megacycles. All medical diathermy and industrial heating equipment which cannot be shielded adequately must employ a frequency in these bands.

The principal trend in this field is the use of higher frequencies and higher powers. Frequencies in the thousands of megacycles have been employed to preheat high-quality plastics materials prior to molding, to defrost frozen foods, and to cook foods. Continuous-wave magnetrons are employed to generate several kilowatts of power at these ultrahigh frequencies, the energy being conducted through waveguides to a chamber containing the material to be heated. Frequencies in the 10-30-megacycle range have

been employed widely to set glue, notably in the furniture and plywood industries. Drying of rayon cakes is also an important potential application.

Lower frequencies are used in metal hardening, brazing, and soldering operations. One of the largest units in metallic service is a 200-kw generator, operating in the hundreds of kilocycles, used to flow tin in the tin plate industry.

An allied technique, not involving the production of heat, is the preservation of foodstuffs by passage of cathode rays through the food. A new electron tube, the capacitron, operates at five million volts and produces an intense beam of cathode rays, limited in duration to a few microseconds. So intense are these rays that they emerge through a thin window at one end of the tube and may be passed directly through food or other perishable substances. The high intensity of the bombardment, coupled with its short duration, excites a preservative radiation within the foodstuff without producing sufficient heat to induce chemical changes. The effect of the bombardment, in the majority of foods thus far tested, is to kill bacteria and other micro-organisms, and to inhibit the activity of enzymes to such an extent that food will remain fresh for months without refrigeration, and in fact with no treatment whatever except cover to prevent loss of moisture. Meat and poultry, fats and oils, vegetables (except lettuce, which wilts under treatment), fruits, and perishable drugs have been treated successfully. The treatment may be applied to food in any form, dried, frozen, raw, partly or fully cooked, as no chemical change is produced by the passage of the cathode rays.

TRENDS IN PROCESS AND MACHINERY CONTROLS

Among the application of electronic controls to machinery and processes, is a notable trend toward the use of thyratron motor controls on small machine tools. Technically this device is not new, but its extensive penetration into the metal-working industries is of recent date. The motor control serves to give smooth control of motor speed and torque without loss of efficiency.

Noteworthy among recent continuous process controls is a register control which combines an electronic computer and a hydraulic mechanism for correcting the register between successive imprintings of colored ink on paper or metal. The over-all performance of this register control is outstanding: register is held with an error on 1/1,000 inch while the printed material is passing through the press at a speed of 1,000 feet per minute. Register marks printed by the first color are viewed by a photoelectric tube which develops a pulse of current as each register mark passes. These pulses are shaped and passed to a computer unit which determines the rate of passage of the marks and detects any difference in the rate relative to the printing speed of the succeeding color. Immediately that such an error is detected, it is amplified to the level of about 25 watts, and actuates an hydraulic valve which drives a differential connected to the printing rolls. The production of a pressman operating a press fitted with this register control is tripled. As the electronic components must operate, in certain applications, in an explosive atmosphere, all tubes and components are immersed completely in oil and sealed hermetically.

Another continuous process control of recent date is the X-ray thickness gauge, used to monitor the rolling of hot-rolled steel sheets. As the sheet is very hot when rolled, simple contact gauges have short life and are inaccurate at best. An X-ray gauge, which does not touch the sheet, operates as follows: an X-ray tube on one side of the sheet irradiates it with rays of intensity just sufficient to penetrate the sheet and cause a fluorescent screen on the other side to emit light. This light is viewed by a photoelectric tube in a balanced circuit; the output of the photoelectric tube is thus sensitive to minute changes in the fluorescent light, such as are caused by very slight changes in the thickness of the sheet. The photoelectric tube current indicates to the mill operator the extent of the thickness variations, and even may be used to maintain the thickness automatically within desired limits.

An application of electronics in the aviation industry, capable of similar savings in costs of operation, is the electronic aircraft engine analyzer. This is a cathode-ray oscilloscope connected to the ignition harness of an aircraft engine in such a way that the voltage across each of the spark plugs individually is represented as a function of time. The resulting wave form is an accurate index of the excellence of the ignition process and in particular will indicate impending ignition failure before it occurs. When so detected, a faulty spark plug may be identified and replaced in a very short time, often while the aircraft is making a scheduled stop. Without the engine analyzer faulty ignition cannot be detected in advance, and the time lost in finding a faulty plug may cost several thousand dollars in revenue lost while the aircraft is out of service.

Among the telemetering devices, one of the most interesting is the application of television to the monitoring of water level in high pressure boilers. To safeguard such boilers, it is customary to install complicated systems of mirrors, and safety laws require an operator to watch the water-level tubes at all times. Extensive research has proved that it is difficult if not impossible, to replace the mirror system with a less cumbersome telemetering system, because the telemetering system might give a false indication and thus place lives and property in grave jeopardy. A satisfactory alternative was found in television, a television camera to view each of several water gauges and a group of viewing screens so arranged that a single observer can monitor several units simultaneously. Television proved satisfactory because it cannot give a wrong indication; it either shows the gauge level properly or it shows nothing at all. In event of failure of the television system, of course, rapid recourse must be taken to the mirror system, which is installed as an auxiliary to the television system.

ELECTRONIC COMPUTERS

As a concluding classification, we shall consider devices which are perhaps the most significant of all electronic devices now in process of development, the electronic computers.

By making possible rapid computations from huge masses of data, problems formerly impossible of solution now may be solved. One possible result is accurate long-range weather forecasting. Another is the computation of

all sorts of mathematical tables, from Bessel functions to nautical almanacs, in weeks rather than years.

Two types of electronic computer have emerged in recent years, the analogue computer and the digital computer. The analogue type is a combination of electronic circuits which is in effect an electronic model of the device or process whose operation is to be computed. Circuits capable of adding, subtracting, multiplying, dividing, differentiating, and integrating are known and may be so combined as to perform a sequence of operations producing directly a variation of current or voltage which represents the desired solution. These computers have the advantage of comparative simplicity, but are limited in accuracy.

The digital computer is, in essence, a counting device capable of extremely rapid action. As all mathematical operations may be reduced to a series notation which is, in effect, a counting process, the digital computer is of extremely wide application and its accuracy may be extended to any desired limit by multiplying the number of counting units. The Eniac computer, one of the first of the digital type, employs 18,000 tubes. A more recent embodiment of this principle, the International Business Machines computer, employs 12,500 tubes and operates with almost unbelievable speed and range. The basic mathematical data are introduced to this machine by punched cards, and similar cards are employed to set up the sequence of mathematical operations. Numbers of 19 digits may be accommodated, and operations may occur at the rate of 24,000 digits per minute. Intermediate totals in a computation may be stored electronically, in electromechanical relays or punched tape, the total storage capacity being 400,000 digits. Using this computer, the position of the moon, an important element of nautical almanacs, may be predicted for any time for hundreds of years in the future, in seven minutes of computing time. The mathematical process involves summing a series of 1,600 terms, that is, performing 9,000 multiplications, 10,000 additions and subtractions, and taking 1,800 values from trigonometric tables.

With such comprehensive mechanisms available, it is certain that vastly complicated processes of nature, particularly those now opening up in nuclear science, soon will be capable of analysis. With the understanding such analysis will provide, we may look forward confidently to a broader and more comprehensive technology.

Two Electrical Essays

Induction Motor Above Synchronous Speed

AN IDEAL transformer may be defined as one in which primary and secondary coils are coupled perfectly, that is, primary and secondary "leakage reactances" are each zero, and where also the resistances of the primary and secondary coils are zero.

The theory of an ideal transformer is very simple, and is approximately valid for an actual transformer. Because of the perfect coupling, or lack of "leakage fluxes," the voltages induced in the coils are strictly proportional to their turns, respectively, and are strictly in phase with each other. Also, except for the small magnetizing current, the ampere turns of primary and secondary are equal and opposite. Hence, the primary and secondary currents, except for the small magnetizing current, have their magnitudes strictly inversely as their turns, respectively, and their phases are strictly opposite to each other.

It follows then, that if the secondary is caused to supply a load, then the primary will take from the line an exactly equal load, as regards true watts, and also as regards the reactive volt-amperes. The last point, which I particularly want to stress, arises from the primary and secondary voltages being strictly in phase, and the primary and secondary currents being strictly opposite in phase.

A similar simple theory may be given for the ideal polyphase induction motor, and this theory again is approximately valid for an actual motor.

When the motor is at rest, it is an ideal static transformer such as was treated in the preceding paragraphs. Again because of the perfect coupling, the voltages induced by the rotating field in the stator and rotor are strictly proportional to their turns, respectively, and are strictly in phase with each other. Again, we also have that, except for the small magnetizing current, the stator and rotor currents will be strictly inversely as their turns respectively as regards magnitude, and strictly opposite each other as regards phase.

Now let the motor run with a slip s, less than one, but greater than zero. The secondary voltage now will be to the primary voltage not as the ratio of turns, n_2/n_1, but will be reduced further by the slip s. That is, we now will have, $e_2 = s\frac{n_2}{n_1}e_1$. The phase of the secondary voltage relative to the primary voltage will not be changed. However, since their ampere turns must continue to annul each other (except for the small magnetizing current) the stator and rotor currents continue to be inversely as their turns, and their phases continue to be strictly opposite, $i_2 = -\frac{n_1}{n_2}i$.

It follows then, that if the rotor is loaded, the stator will need to be supplied with power, $e_1 i_1 = \frac{e_2}{s}$ or $\frac{1}{s}$ times the power delivered by the rotor, and this holds not only for the true power, but also for the reactive power. The difference in true power, $\left(\frac{1}{s}-1\right)e_1 i_1$, is, of course, the power delivered as mechanical power to the shaft. The difference in reac-

tive power we account for, by reflecting that the reactive power we account for, by reflecting that the reactive power associated with a given magnetic energy is proportional to the frequency and that therefore, because of its lower frequency, sf, the smaller reactive power, $e_2 i_2 = s e_1 i_1$, of the rotor corresponds to just as much magnetic energy as the larger reactive power of the stator.

The rotor might be loaded by connecting its slip rings to a static impedance, $Z = R + jX$. Then the load taken from the line will be the same as if an impedance $\frac{1}{s}\left(\frac{n_1}{n_2}\right)^2 (R+jX)$ were connected to the line. We note again that the line reactive power is of the same sign as the rotor power, lagging if the latter lags, and leading if the latter leads.

Let us now run the rotor at above synchronous speed, that is, with a negative slip, which we shall denote by $-s$. Now the rotor induced voltage will be *opposite* in phase to the stator induced voltage, $e_2 = -s\frac{n_2}{n_1}e_1$. The stator and rotor currents, however, continue to be in opposite phase relationship, $i_1 = -\frac{n_2}{n_1}i_2$. Thus, as compared with running below synchronism, with positive slip, s, we see that above synchronism, the relative phases of the stator and rotor voltages are reversed, whereas the relative phases of the stator and rotor currents are unchanged. We conclude then, that above synchronism, the stator power will be opposite in sign to the stator power below synchronism.

Consider again the case where the rotor is loaded by a static 3-phase impedance, $Z = R + jX$, across its slip rings, and compare the operation at slip $-s$ above synchronism, with slip s below synchronism. The rotor frequencies will be the same in the two cases; namely, $f_r = sf_o$. Hence the static impedance Z will have the same value, $R + jX$, in the two cases. The rotor voltages in the two cases, E'_2 and E_2 will be the same in magnitude, but opposite in phase, $E'_2 = -E_2$. The rotor currents, therefore, will be opposite in phase in the two cases, $I_2' = \frac{E_2'}{Z} = \frac{-E_2}{Z} = -I_2$. The stator, or line voltages, are of course the same in the two cases, $E_1' = E_1$. The stator currents however, which must be opposite in phase with the rotor currents, will be opposite in phase in the two cases. $I_1' = -\frac{n_2}{n_1}I'_2 = +\frac{n_2}{n_1}\frac{E_2}{Z}$; $I_1 = -\frac{n_2}{n_1}I_2 = -\frac{n_2}{n_1}\frac{E_2}{Z}$; therefore, $I_1' = -I$.

Thus again we conclude that the stator power at the slip $-s$, above synchronism, is equal to but opposite in sign for the stator power at the slip s below synchronism.

In an actual motor, of course, the rotor will have a resistance and a leakage reactance which should be added to the slip ring impedance in the previous example. If the slip rings are short-circuited, then the total effective rotor impedance is just this rotor resistance and rotor leakage reactance.

We conclude then that an induction motor with short-circuited winding, at an oversynchronous speed, slip, $-s$, will take power from the line very nearly equal and opposite to the power taken at below synchronous speed, slip s. Below synchronous speed the motor takes positive true power from the line, and also positive (lagging) reactive power.

Hence above synchronism, the motor will deliver true power to the line and also deliver reactive power to the line. That is, the induction motor above synchronsim operates at leading power-factor.—*True* or *false?*

Answer to Previous Essay

The author's reply to his previously published electrical essay (*EE, Jun '48, p 530*) is as follows.

Take a long rectangular strip of paper. Give the strip a half-twist, that is, turn one end 180 degrees relative to the other, then overlap the two ends and glue together. As may be seen from a model or the figure, the strip now constitutes a smooth, continuous surface bounded by a *single*, smooth, continuous, closed curve. Nevertheless, Faraday's law is not true for this surface bounded by this curve.

The statement of Faraday's law should have included the restriction that the surface is two-sided. Of the books on the library shelf in this laboratory dealing with vector analysis or electromagnetic theory, only Stratton's "Electromagnetic Theory" mentions this condition.

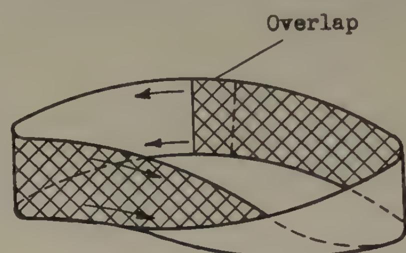

Figure 1

The necessity for this two-sidedness becomes evident when we consider how the sign of the integrals occurring in Faraday's law are to be determined. We may take one particular sense of going round the bounding curve as positive. If then the surface is two-sided, we may use a right-hand rule or some equivalent to determine which side shall be regarded as having the positive normal direction. If the surface is one-sided, however, as in the Figure 1, it becomes impossible to determine a positive normal direction related in some definite way to the direction along the bounding curve which is chosen as positive.

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Measuring Leakage Reactance

To demonstrate and measure leakage reactance, the two windings of a 230-230-volt transformer were connected in series bucking. A reduced voltage sufficient to circulate rated current of 22 amperes was applied. To measure the voltage, a 6-volt a-c voltmeter having a resistance of 24 ohms was connected. The deflection was slightly more than full scale so it was decided to measure the voltage across one winding and double that value to obtain the total voltage. When the voltmeter was connected across either winding there was no observable deflection of its pointer from a zero reading. Why is such a result obtained?

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Mobile Radio Communication

AUSTIN BAILEY
MEMBER AIEE

THE FIRST EXPERIMENTS in radio communication with automobiles appear to have been made in 1921 by the Detroit police department. In 1927 the experiments were renewed and by April of 1928 the Detroit police had a system in successful operation. Experiments having proved the utility of the 30-40-megacycle band for car-to-land transmission; power utilities, traction companies, and others having use for emergency communication began making radiotelephone installations. An emergency radiotelephone service which for the first time provided connections to any telephone began operation in New York, N. Y., on December 5, 1940. In 1939, experiments indicated that frequency modulation held much promise and appeared to be superior to the conventional amplitude modulation employed up to that time for radiotelephone service from vehicles. Advanced techniques, overcrowding in the 30-40-megacycle band, and opening of the 152-162-megacycle band stimulated expansion.

Operation of a small radio system is usually on a single-frequency basis as shown by Figure 1. If the community is one of a cluster of small municipalities, then it is customary to resort to 2-frequency operation to reduce interference.

The usual small station employs a combined transmitter-receiver unit mounted in a console and installed on the back of a desk, and a coaxial antenna. The console cabinet contains, in addition to the transmitter chassis and receiver chassis, a loud-speaker, antenna transfer equipment, operating keys, pilot lights, and possibly meters. The typical mobile installation consists of a transmitter and receiver installed in the trunk of a car; a roof top antenna; and a control head, handset, and loud-speaker installed inside the driver's cab of the car. The mobile unit obtains power from the 6-volt car battery.

In a larger city, because the transmitting and receiving equipment must be relatively close to the antenna and the operating point may be at another location, some form of remote control is required. Usually a telephone line between the operating point and the radio transmitter-receiver site is used. The direction of operation of the line is reversed by the operator from the control point, through the use of a suitable control circuit. Systems for large cities generally are operated on a 2-frequency basis, shown in Figure 1, with some of the mobile units equipped for car-to-car communication. There also may be some vehicles equipped for receiving only.

Communication systems providing statewide coverage associated with a larger number of mobile units usually are operated on a 2-frequency basis to permit simultaneous usage of several land stations with minimum interference. Some systems are 2-way but the so-called 3-way systems, shown in Figure 1, are becoming increasingly popular. A state-wide radio system in which all land stations are tied together by a voice-frequency wire network and a teletype network, has been placed in service by the New York State Police.

The combination of wire and radiotelephone communication circuits, offers an opportunity to provide a logical extension of telephone service to large groups of mobile units on a common carrier basis. The mobile subscriber uses an instrument similar to the telephones commonly employed by the public. The calling arrangement rings a bell only in the automobile of the one subscriber with whom communication is desired. Systems for common carrier use have been put into operation at a number of places throughout the United States. There were 102 land stations providing service to about 4,000 mobile units at the beginning of 1948.

To provide service to more than a very few of the automobiles in a large city area, more than a single radio channel must be employed. The primary problems encountered in attempting to operate radio systems closely spaced in frequency and in location include insufficient receiver selectivity, intermodulation between several land transmitters in close proximity, and intermodulation in nonlinear stages of land and mobile receivers.

Digest of paper 48-125, "Mobile Radio," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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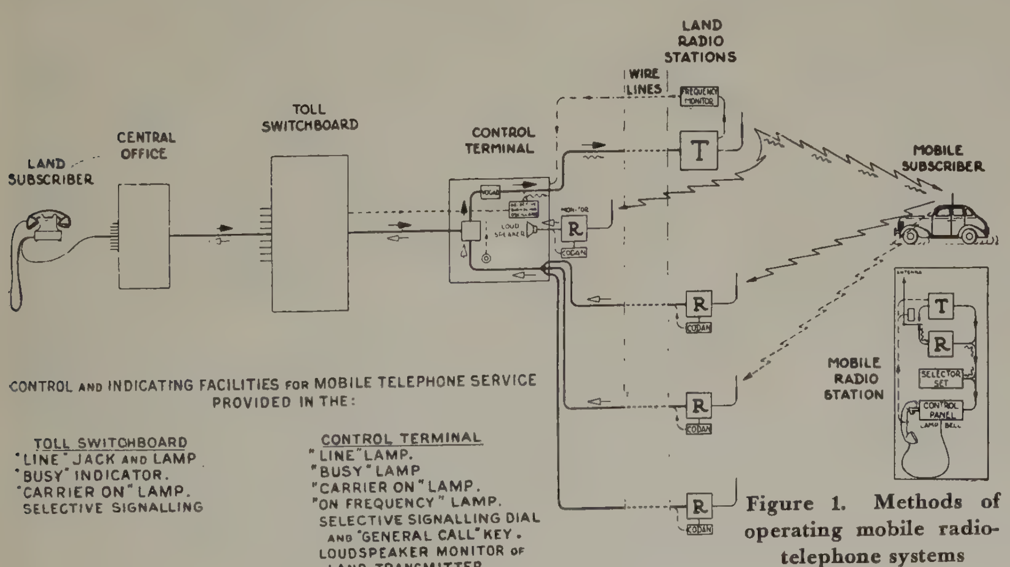

Figure 1. Methods of operating mobile radio-telephone systems

Technological Problems in Mexico

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FELLOW AIEE

IN REVIEWING some of Mexico's most significant technological problems (as observed in several years of study by the Armour Research Foundation), it is necessary to recognize that, in general, manufacturing industries are new to Mexico. Agriculture and the extraction of crude minerals have been the principal activities until fairly recent years, and are still among the most important in volume. The largest part of the conversion of Mexican raw materials into finished products has been done through exportation of the raw materials to other countries. The adverse economic effect of this is not the subject of the present article although it is the very heart of Mexico's industrialization problem. The pertinent fact is that under this procedure the manufacturing technology for these products has been applied and developed continuously in other countries such as the United States, but not appreciably in Mexico itself.

Therefore, while the need for Mexican engineers and technical men has grown progressively with the discovery of new natural resources, the opportunity for them has come only recently and suddenly with the introduction of large-scale "industries of transformation"—the domestic conversion of raw materials into finished manufactured goods for home consumption and for the markets of the world. The cycle which we have seen in the United States—that of domestic manufacturing payrolls absorbing more production, encouraging still more production, and thus creating more payrolls or purchasing power for both domestic and imported goods—is under way in Mexico. And at last there is a place on these payrolls for the Mexican engineer. Now, perhaps, it will seem worth his while to study engineering and science. Before now, it is safe to say that many a natural-born Mexican technologist had studied law or medicine instead to be able to make a living. The situation is still far from good but it is improving. The suggestion of certain ways in which everyone can co-operate toward the mutually advantageous industrial and economic growth of the republic therefore seems to be pertinent.

The technical schools of Mexico, whose traditional emphasis has been upon theory, must adjust themselves to the present actual needs of the country. The establishment of new manufacturing industries in Mexico is creating a demand for Mexican engineers and this demand must be met by the amplification of present engineering courses; laboratory instruction, practical engineering training, and applied research must be emphasized, possibly at the expense of some theoretical subjects. Notable progress is being made in this direction. Meanwhile, industry itself must help financially in the educational program by the establishment of scholarships and by gifts and endowments to technical schools.

Better application of technical personnel is needed in industries of all types to raise the quality and uniformity of manufactured goods. Increased foreign trade—to create dollar exchange, for example—can be secured only if Mexico's products are of a character acceptable on the world market in competition with those of other countries.

While Mexico's contribution in fundamental research is good, the principal need in the present stage of national development is for applied research, and this essential factor is almost entirely lacking. A great amount of applied research is needed to develop natural resources, improve agricultural yields, raise the quality and uniformity of manufactured products, increase production efficiencies, and to develop new industrial processes for the production of valuable materials from resources native to the country.

To accomplish these things Mexico must continue to import technology for the present. However, in all technological importation—whether through companies, scientific agencies, government, or private engineering firms—it is important that the training of additional Mexican technical men be included in some way, so that the money spent for such importation can be regarded as an investment for the future rather than as a mere expenditure of principal.

Very recently, and especially since the Mexican-American conference on industrial research, appreciable progress has been made in the establishment of industrial research facilities in Mexico. Legislation has been passed to create an independent nonprofit industrial research institute. Pending the actual establishment of such an institution, facilities for the solution of immediate applied research problems have been placed in operation through the joint efforts of the Armour Research Foundation and the Banco de Mexico, S. A.

In conclusion, it seems appropriate to offer several ideas to aid in what Mexico is trying to do. To Mexican capitalists, it is suggested that more serious consideration be given to the endowment of universities, research institutes, and libraries for technical work and training. To Mexican industries it is urged that more use be made of the technology that is now available to them. To equipment manufacturers both here and in the United States, it is suggested that donations of equipment to Mexican schools for practical training can bring the same double benefits received elsewhere through this procedure. To the Mexican schools and universities, it is proposed that their efforts to increase the practical aspects of technical training be continued, even if at the expense of some of the more obscure theory. And to others, it is sufficient to say that our actions should be guided by the knowledge that the success of Mexico's program is equally important to all of us.

Digest of paper 48-179, "Some Aspects of Research and Technological Development in Mexico," recommended by the AIEE research committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Thermoelectric Generator Designs

GRENVILLE B. ELLIS

During the recent war, characteristics such as extreme portability and low maintenance inspired renewed interest in the thermoelectric generator as a portable power supply. This article considers the thermoelectric effect in the conversion of heat to electric energy as the last of a series of articles reviewing the various known and tried methods of producing electric power in the light of present-day knowledge. With its completion, the entire series* is scheduled to be made available in pamphlet form.

THE CONVERSION of heat to electric energy by the phenomena of thermoelectricity has been considered for many years as a desirable means of obtaining pure d-c power which does not require moving parts and as much maintenance as presently exists, especially in the present types of generators that are driven by gasoline engines. As near as can be determined, the earliest observations of the thermoelectric effect were made by Seebeck in the early part of the 18th century. During the 18th century many inventors attempted to produce a thermocouple that could be incorporated into a generator that would be accepted generally by the public as a practical power source. In most instances, however, these designs resulted in conversion units that were wasteful of fuel and were large and cumbersome, as well as unreliable and expensive to construct. Toward the end of the 18th century, as rotating equipment for the production of a-c and d-c power became more universal, further attempts to perfect thermoelectric generators received less impetus. There seems no thermoelectric generator that has been developed that approaches the efficiency of present conversion units, such as motor generator sets and gasoline-engine-driven generators. A close examination of the past work has indicated that the approach to the solution of the problem was not always sound, mostly because the scientific tools with which the researchers worked were not as highly developed or as plentiful as they are today, the choice of materials not as large, and the understanding of material structures not as well understood. It is true, even today, that the understanding of material structure is not too clearly understood when working with materials other than metals, but is sufficiently well advanced to set up methods by which a scientific approach can be laid out.

The recent war brought about renewed interest in thermoelectric generators as they did offer certain characteristics for portable power supplies that fitted into the military picture. These characteristics were extreme portability, quietness of operation, a pure source of d-c power, low maintenance, as well as certain practical considerations such as a source of heat for personal comfort and preparation of food. Experimental work was conducted by the Army to the point where some types of thermoelectric generators were used. The elements of these units were chromel-constantan couples and were heated by wood, charcoal, and, in some instances, gasoline, as required. The use of these, as crude as they seemed, did indicate that a definite place for such generators existed provided that their over-all efficiency could be brought into line with portable engine-driven generators. It was not believed practical to consider such generators for large power but to examine their use in the 200–300 watts range where engine and generator maintenance in present units always has presented a major problem. The results of research and resultant generator design may change this thinking radically and very well could result in consideration of higher power units.

The present types of generators have a ratio of weight to power of about 2.1 pounds per watt, including gasoline fuel for eight hours operation. Generators were designed up to 40 watts output, having this ratio. The maximum potential provided in any of these generators was on the order of 12 volts. It is understood that the Eaton Manufacturing Company, Cleveland, Ohio, has done some work on a 90-volt unit believed to be the only commercial unit developed in recent years. The efficiencies of these units ranged in the order of 0.2 of one per cent based on an over-all efficiency from fuel to d-c power output and was not truly indicative of the possible efficiency as a considerable improvement could have been obtained if more practical use could have been made of the heat available from the source.

An analysis of these generators indicates three general problems that must be considered in any program which is intended to improve the over-all efficiency to a point where it can become a competitive power supply to existing conversion units. These involve the following:

1. Thermocouple for maximum power efficiency.
2. Optimum heat transfer system.
3. Proper heat source.

These three present difficult and complex design problems, especially when economy, weight, size, noise, and efficiency are being considered. It is impossible to divorce one from the other as they are interdependent.

The development of an efficient thermocouple is probably the most important first consideration because there must

Essentially full text of a conference paper presented at the AIEE Midwest general meeting, Chicago, Ill., November 3–7, 1947.

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The author wishes to acknowledge the assistance of Doctors Kurt Lehovec and Otto Sherzer of the Signal Corps Engineering Laboratories in the preparation of the theoretical equations.

* The following articles previously have been published in *ELECTRICAL ENGINEERING* on the subject of electric power sources: "Electrostatic Sources of Electric Power," John G. Trump (*EE, Jun '47, pp 525–34*); "Nature and Use of Piezoelectricity," W. G. Cady (*EE, Aug '47, pp 758–62*); "Electric Power Sources," L. W. Matsch, Wilbur C. Brown (*EE, Sept '47, pp 880–1*); "Electrochemical Sources of Electric Power," George W. Vinal (part 1, *EE, Apr '48, pp 354–7;* part 2, *EE, May '48, pp 456–65*); and "Magnetostriction Generators," J. A. Osborn (*EE, Jun '48, pp 571–8*).

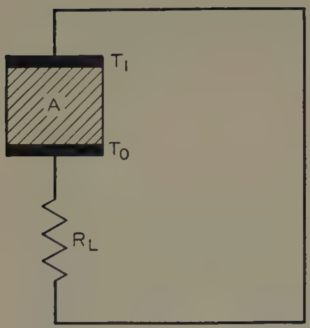

Figure 1. Typical thermocouple composed of two materials, A and B

be a certain minimum acceptable efficiency in the couple and this minimum will determine whether it is practical to proceed with the balance of the generator. It is understood readily that this efficiency should be as high as practical and higher than any obtained to date on any observed couple combinations.

Research has been initiated by the Signal Corps to determine if such a couple can be formulated and what its characteristics should be. A theoretical study can give us a clue as to what the order of some of the thermal and electrical characteristics should be and is helpful in determining the direction toward which work should proceed.

The following equations have been derived from a simple case, using constants and formulas that apply to metals, because the theory of metals is worked out reasonably well and still will serve as a fairly good guide. When the field of nonconductors or any deviation from metals is considered, these equations do not fully apply and adjustments necessarily must be made.

THEORETICAL CONSIDERATIONS

A thermoelectric generator can be thought of as a heat engine in which the working substance is the electron gas whose flow constitutes the electric current. In a thermocouple we will consider a hot junction at a temperature T_1 and a cold junction at a temperature T_0. The thermodynamic efficiency then would be

$$\text{Eff} = \frac{T_1 - T_0}{T_1}$$

Assuming a practical maximum and minimum operating temperature gradient of 900 degrees centigrade maximum and 500 degrees centigrade minimum, with the cold junctions in either case held at 100 degrees centigrade, the efficiency based on thermodynamic considerations would be in the range of 52 per cent to 68 per cent. The Thomson effect would reduce this slightly. The result is still a good indication that a thermocouple of good efficiency is not limited entirely by thermodynamic considerations. The calculation indicates the desirability of maintaining a large operating temperature ratio of T_1/T_0.

It is now desirable to determine what factors control just how much of the indicated efficiency can be obtained from a properly designed couple. It is necessary to base the following calculations on metals as very little is known about the characteristics of nonconductors, semiconductors combined with trace elements. Equations can be set up which, in general, will indicate the parameters within which to work and will indicate where the emphasis must be placed in the search for a high efficiency power-producing thermocouple.

The technical factors of designing a thermocouple involves fairly well-known mathematical assumptions and straightforward calculations, provided such calculations are based on the use of metals. Where materials other than metals are considered, it will be necessary to substitute experimental data in the equations to obtain more accurate results because some of the values of the constants will not hold true in such cases.

The calculations are based on the following energy terms:

1. Electric power output.
2. Electric power loss resulting from the internal resistance.
3. Peltier effect at the junctions.
4. Thomson effect within the connector wires.
5. Heat conduction within the wire.

The Thomson effect can be disregarded as being too small to affect the results. Figure 1 represents a typical thermocouple composed of two materials A and B and will be characterized by the following quantities:

Electrical resistance R_A, R_B
Electrical conductivities σ_A, σ_B
Thermal conductivities K_A, K_B
The Peltier voltage between the two materials:
$\pi = C_t T$

The electric current in the system then is

$$I = \frac{C_t T_1 - C_t T_0}{R_L + R_A + R_B}$$

The heat flow H is given in the expression:

$$H = (T_1 - T_0)C_H; \quad C_H = \frac{K_A}{\sigma_A R_A} + \frac{K_B}{\sigma_B R_B}$$

The energy per second that is absorbed by the hot junction in its heat medium is, therefore

$$W_a = C_t T_1 I + H = C_t^2 T_1 \frac{T_1 - T_0}{R_L + R_B + R_A} + C_H(T_1 - T_0)$$

The useful power in the load R_L then is

$$W_L = R_L I^2 = RC_t^2 \frac{(T_1 - T_0)^2}{(R_A + R_B + R_L)}$$

The efficiency of the thermocouple can then be calculated from the equation:

$$\frac{1}{\eta} = \frac{W_a}{W_L} = \frac{(R_A + R_B + R_L)T_1}{R_L(T_1 - T_0)} + \frac{(R_A + R_B + R_L)^2}{R_L C_t^2 (T_1 - T_0)} C_H$$

An examination of this equation indicates that the maximum efficiency will be given by a certain ratio of the resistance R_A, R_B, and R_L. To find this optimum ratio we first differentiate with respect to R_L.

Table I. Some Fairly Well-Known Materials Whose Thermoelectric Effect Has Been Observed

The Materials Were Measured Against Platinum at Degrees Centigrade With the Material on Test at 200 Degrees Centigrade

	Millivolts	Temperature, C
Galena	−98	200
Cuprous sulphide	62	200
Marcasite	55	200
Cupric sulphide	43	200
Arsenical pyrite	53	200
Iron pyrite	21	200
Silicon	−81.67	200
Tellurium	9.3	200 (single crystal)
Cd-Sb	45.6	100
Se_2Sn	39.3	100
TeSe	68.4	100
Germanium	72.4	200

$$\frac{d}{dR_L}\frac{1}{\eta}=-\frac{(R_A+R_B)T_1}{R_L^2(T_1-T_0)}+\left(1-\frac{(R_A+R_B)^2}{R_L^2}\right)\frac{C_H}{C_t^2(T_1-T_0)}$$

Equating this to zero we obtain

$$R_L=(R_A+R_B)\sqrt{1+\frac{3T_1}{T_k}}$$

with the term

$$T_k=\frac{3C_H}{C_t^2}(R_A+R_B)=\frac{3K_A}{C_t^2\sigma_A}\left(1+\frac{R_B}{R_A}\right)+\frac{3K_B}{C_t^2\sigma_B}\left(1+\frac{R_A}{R_B}\right)$$

Introducing T_k into $\frac{1}{\eta}$ we obtain

$$\eta=\frac{3(T_1-T_0)}{(\sqrt{T_k+3T_1}+\sqrt{T_k})^2}$$

T_k is an expression which may be called the characteristic temperature of the thermocouple. This expression involves the Peltier heat effect, thermal conductivity, and electrical conductivity, and is the temperature at which the heat taken from the hot junction by the Peltier effect and the heat loss from the hot junction by thermal conduction is equal.

This equation indicates the smaller the quantity T_k the larger the efficiency will be.

To find the ratio of R_A/R_B for which T_k is a minimum, we differentiate with respect to R_A:

$$\frac{dT_k}{dR_A}=-\frac{3K_AR_B}{C_t^2\sigma_AR_A^2}+\frac{3K_B}{C_t^2\sigma_BR_B}$$

Equating this to zero we obtain

$$\frac{R_A}{R_B}=\sqrt{\frac{K_A\sigma_A}{\sigma_AK_B}}$$

with this optimum ratio we find

$$T_k=\frac{3}{C_t^2}\left(\sqrt{\frac{K_A}{\sigma_A}}+\sqrt{\frac{K_B}{\sigma_B}}\right)^2$$

An examination of these equations shows that with T_k in the denominator of η, the efficiency becomes larger, as the Peltier constant C_t and the electrical conductivities σ_A and σ_B become larger. Also, as the thermal conductivities K_A and K_B become smaller, the efficiency improves. If all these conditions are ideal we readily can see that the optimum condition for thermal efficiency would be approached as expressed

$$\eta\text{th}=\text{efficiency}=\frac{T_1-T_0}{T_1}$$

Table II. Thermocouples Whose Thermoelectric Effect Has Been Observed

	Millivolts	Temperature Gradient
Silicon-silicon carbide	400	1,220 F
Carbon-silicon carbide	473	1,600 F
Graphite-boron carbide	600	2,050 C
Silicon carbide-boron carbide	1,200	2,050 C (approximate)

The Signal Corps Engineering Laboratories has in force a research contract with The Franklin Institute, Philadelphia, Pa., to conduct fundamental research studies leading to the development of high efficiency power producing thermocouples and a better understanding of thermoelectric effects.

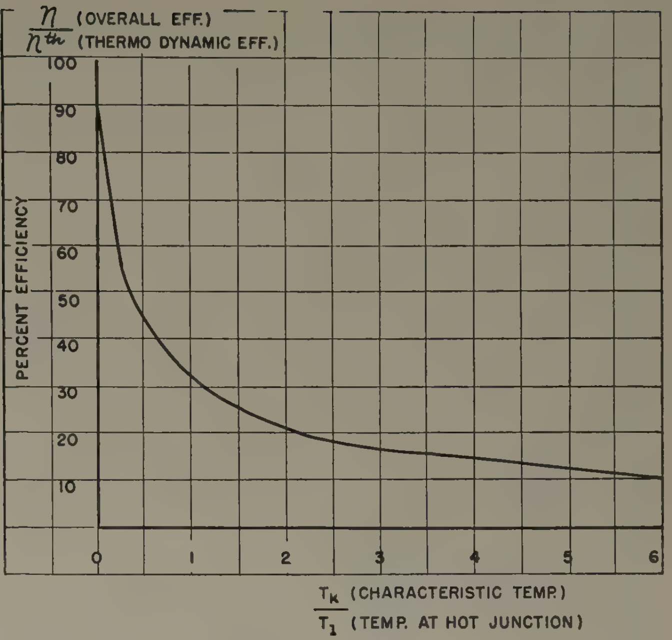

Figure 2. Effect of thermoconductivity on over-all efficiency

if we write η in the form

$$\eta=\frac{T_1-T_0}{T_1}\cdot\left(\sqrt{1+\frac{T_k}{3T_1}}+\sqrt{\frac{T_k}{3T_1}}\right)^{-2}$$

Here the second factor shows how much the efficiency is decreased below ηth by the influence of heat conduction. We can see that an increase of T_1 increases both the factors composing η.

Figure 2 shows how the second factor depends on T_k. For the case of metals, where

$$\frac{K_A}{\sigma_A}\approx\frac{K_B}{\sigma_B}\approx 1\frac{\text{volt}^2}{\text{degree centigrade}}$$

Figure 3 shows the dependence of T_k on the thermocoefficient c_t. If, for instance, we have $c_t=\frac{200\text{ microvolts}}{\text{degree centigrade}}$ Figure 3 yields $T_k=3{,}000$ degrees Fahrenheit and for a T_1 of 1,000 degrees Fahrenheit $\approx$ 820 degrees Kelvin, Figure 2 yields $\eta=1/6\ \eta\text{th}\approx 10$ per cent.

OPTIMUM HEAT AND HEAT TRANSFER SYSTEM

The selection of the heat source and heat transfer system will depend largely on the temperature at which the hot junction is to be maintained for maximum practical power output. This selection cannot be made until the thermocouple design and characteristics have been settled completely. This assumes that a heat transfer system of greatest economy is to be used. Where efficiency is to be sacrificed because the fuel is cheap or other conditions exist which do not depend on economy, the solution only is influenced by the safe operating temperature of the hot junction.

Most metallic thermocouples require and safely can use rather high temperatures at the hot junction to obtain high efficiency. When the temperatures exceed 1,000 degrees Fahrenheit and require heat from direct burning of fuel, it is usually necessary to use a forced draft system to maintain the heat at the hot junctions. Such systems are wasteful

and do not lend themselves to high over-all efficiency. In cases where electric heating is used, suitable insulation can be supplied that will reduce the heat losses considerably.

When semiconductors or materials that require lower operating temperatures at the hot junction are considered, there are many systems for heat transfer that may be investigated. The use of heat transfer fluids that can withstand temperatures in the order of 900 degrees Fahrenheit for prolonged periods are perhaps the most promising at this time. The hot junctions can be immersed in the fluids in an insulated container to reduce heat losses. The design of such a container with insulation to reduce radiation can use flash boiler principles for transferring the heat from the source to the junction more rapidly and can arrange for rapid circulation of the fluid past the heat source. A system such as this would present an evenly distributed temperature to all hot junctions and could be designed to maintain the temperature at the maximum safe operating temperature at the hot junctions.

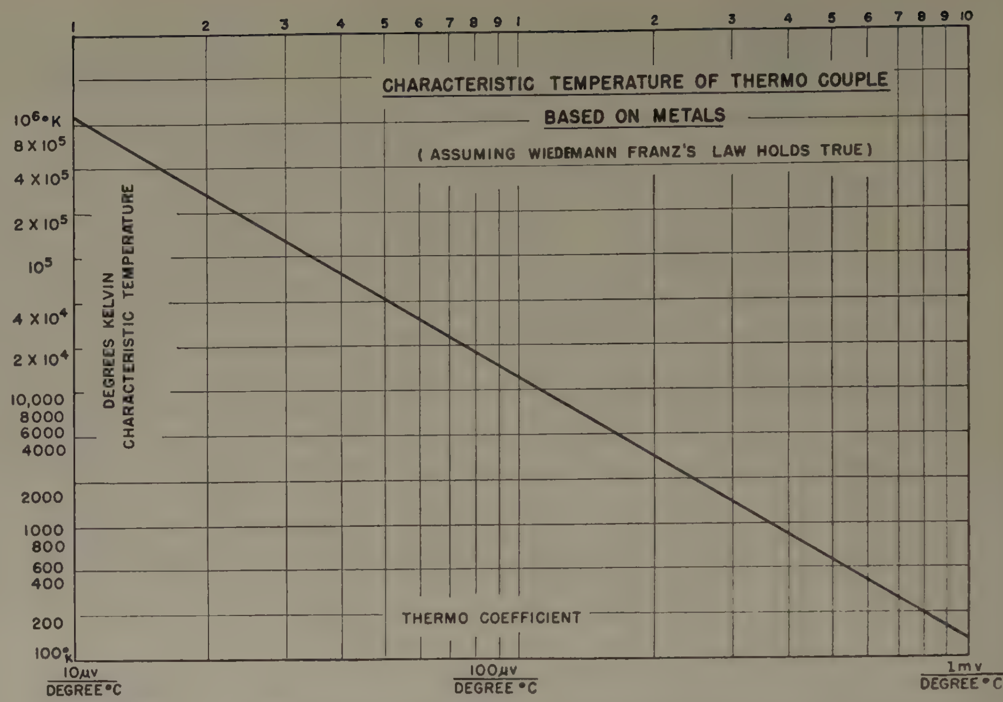

Figure 3. Characteristic temperature of thermocouple based on metals

For moderate temperature hot junctions some consideration could be given to the direct burning of fuel such as used in conventional kerosene stoves, direct burning of gasoline by a properly designed gravity feed system. Coal, wood, and many other fuels could be considered without the need for a forced draft. It can be seen that a properly designed thermocouple with a low operating temperature would simplify the heat transfer system considerably and would assist in overcoming the loss of heat that normally would pass up the flue by allowing the use of a heat transfer system where the rate of heat transfer required is not so rapid as for high temperature hot junctions.

It can be stated generally that the efficiency will have a direct ratio to the temperature required at the hot junction from the practical considerations of the system design.

CONCLUSIONS

The study of the over-all concepts of thermocouple and generator design, both from the theoretical and practical point of view, has indicated certain parameters which are believed to indicate some physical and electrical characteristics which must be satisfied before a thermocouple could be considered seriously as an efficient power source. Some of the most important are the following:

1. Maximum hot junction temperature of approximately 1,000 degrees Fahrenheit.
2. Potential characteristic of 600 microvolts per degree centigrade.
3. The structure should be mechanically strong.
4. Low internal resistance.
5. Should resist oxidation over prolonged periods.

Observations of literature and experimental data show that such a couple has not been developed as yet. The examination of the characteristics of metals indicates that a combination of metals would not produce such a couple. The best approach may be in the field of semiconductors, incorporating trace elements to adjust properly the thermal and electrical conductivity, and structural characteristics.

The application of quantum mechanics and a complete review of materials by the application of the electron theory may result in a couple whose lattice structure has the optimum desired characteristics.

Such a generator properly worked out, with an efficiency in excess of eight per cent, would revolutionize conversion units in the small power field and find a definite place for itself in the commercial and military fields of application.

Appendix. Nomenclature

A = referring to material A
B = referring to material B
R_A = resistance of material A
R_B = resistance of material B
R_L = resistance of the load
π = Peltier coefficient
C_t = thermal current
T = temperature, degrees Kelvin
σ_A = electrical conductivity of material A
σ_B = electrical conductivity of material B
K_A = thermal conductivity of material A
K_B = thermal conductivity of material B
H = heat flow
T_1 = temperature at the hot junction
T_0 = temperature at the cold junction
η = efficiency
th = ideal thermodynamic efficiency
W = power
T_k = characteristic temperature of material
I = total electric current
K = thermal conductivity $\frac{K_a}{L}$
a = cross section area

The Grand Coulee Power Development

S. M. DENTON
ASSOCIATE AIEE

THE GRAND COULEE power development is a part of the Columbia Basin Project which is primarily an irrigation enterprise. The Grand Coulee dam raises the water level in the Columbia River over 300 feet, but a tremendous amount of power is required to raise water an additional 300 feet for irrigation purposes. This power requirement can be met largely by off-peak power developed at the Grand Coulee power plant consisting of two powerhouses which will have an ultimate installation of almost 2,000,000-kva generating capacity.

The irrigation development will bring water to one of the largest bodies of undeveloped land in the United States. The proposed power installation when completed will exceed any power plant output of today. The cost of power from the Grand Coulee development will compare favorably with the cost of the most economical sites in North America. The low cost of power at this site makes pumping of water for irrigation purposes economically feasible. The Grand Coulee dam which is approximately 4,200 feet long is provided with a 1,650-foot wide spillway designed to discharge 1,000,000 cubic feet per second flood flow. A power plant is located at each end of the dam. The location and length of the spillway section left insufficient space at either end of the dam for the complete power development. The amount of power to be developed and the limited space available indicated units of the largest practicable size should be used. The size of the turbines was determined by the limits of foundry practice and shipping clearances.

Nine generating units driven by hydraulic turbines, each rated 150,000-horsepower at 330-foot head and 120 rpm, are installed in the left powerhouse. The right powerhouse will house nine similar units. The generators, which are the largest water wheel generators in existence, are rated at 108,000-kva, unity power factor, 13,800 volts, and are direct-connected to the hydraulic turbines.

The remoteness of the Grand Coulee plant and the lack of system development in this region at the time the original generators were purchased necessitated considerable study to determine generator characteristics which would be suitable for any reasonable transmission requirement. It was assumed that long distance transmission would be involved with associated stability problems. Low transient reactance and high short-circuit ratio values were specified, together with high speed excitation.

Control, indication, instrumentation, protection, and annunciation are provided at the unit control boards located in the governor gallery adjacent to each turbine governor, and the main control boards located in the main control room. The main control system includes hydraulic governor control, voltage regulation and excitation control, equipment protection, and load and frequency control.

In general, the unit system is employed at the Grand Coulee power plant with the generators connected directly to the transformers. The generator neutrals are to be connected to ground through a distribution transformer with a resistor connected across the secondary windings of the transformer. All switching is accomplished at transmission voltage except for unit *L-1* and the switching required in connection with irrigation pumping. Six generating units in the left powerhouse each will furnish power at generator voltage to drive two 65,000-horsepower motors for pumping irrigation water from Lake Roosevelt in the Grand Coulee balancing reservoir.

The present 230-kv bussing is unusual in that an interleaved system is used whereby the line reactances are used to limit circuit breaker duty. Half of the generators and half of the lines are on each of two busses. The lines tie these busses together and maintain the system tie. This scheme now is being abandoned in favor of a ring bus having five sections. The ring bus arrangement will require circuit breakers of 10,000-megavolt ampere interrupting capacity, but has operating advantages. The generating units have performed satisfactorily connected to the transmission system of very long lines. Loads of 180,000- to 200,000-kva for one line have been common.

Figure 1. View of Grand Coulee dam

Digest of paper **48-123**, "The Grand Coulee Power Development," recommended by the AIEE power generation committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Selecting Inherent Overheat Protectors

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APPROXIMATELY 40 PER CENT of all fractional horsepower motors of one-eighth horsepower to one horsepower split phase and capacitor types made in 1947 were built with inherent overheat protective devices. Field requirements make it desirable that a higher percentage of motors be equipped with inherent overheat protectors. To accomplish this, protector standards and standardized methods of applying protectors must be developed.

The fractional horsepower motor industry has adopted many standards such as mounting dimensions, over-all dimensions, ratings, and speed, but the load demands of fractional horsepower motors are so varied that it is necessary frequently to vary windings to get the desired characteristics. Inherent protectors are temperature sensitive as well as current sensitive devices. Each time the winding or the mechanical features of the motor are varied, it may become necessary to use a different protector than had been specified for a standard winding and standard mechanical assembly.

As inherent overheat protected motors must be approved by the Underwriters' Laboratories, the application of the protector and its approval by the Underwriters' Laboratories have required so much time as to be a hardship on the motor manufacturer and the motor user. To relieve this situation it is desirable to find one or more methods of protector selection based on motor design information. These methods must give acceptable results to the Underwriters' Laboratories.

Digest of paper 48-187, "A Method of Selecting Inherent Overheat Protectors Based Upon Motor Design Information," recommended by the AIEE domestic and commercial applications and the rotating machinery committees, and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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One of the first steps in the solution of this problem is to establish basic information on heating characteristics of the motors resulting from various mechanical features which influence the rate of heat dissipation, the effect of wire size, horsepower, amount of iron, and the temperature of the protector location. A second step is the necessity of protector standardization which will give relatively uniform spacing between ratings as illustrated by ultimate protector tripping curves in Figure 1. It is necessary also that published information on protectors be of a greater degree of accuracy than previously. One may realize the magnitude of this problem when it is understood that first arbitrary methods of testing must be established and that the majority of test data deal with temperature measurements where accumulated errors may be as much as ±3 per cent. This makes it very difficult to attain the desired production tolerance of ±5 per cent for motor winding temperatures at ultimate protector tripping.

The tolerances involved include

1. Tolerances necessary because of inaccuracies in temperature measurements.
2. Tolerances caused by variations in the application of protector to motor. (With standard mountings most of this tolerance variation stems from the steps between standard ratings.)
3. Tolerance caused by variations in production of protectors.
4. Tolerances caused by current and thermal variations in production motors.

In the case of a particular protector applied to a specific motor, the tolerance is approaching ±5 per cent. The over-all tolerances are approaching ±10 per cent. This is a considerable improvement over what can be expected with remote protectors where the over-all tolerance experienced in the field is probably as much as ±25 per cent. As more thermal studies are made of motors, protectors, and the combination of motor and protector, it is hoped that the over-all tolerance can be reduced to ±5 per cent.

Though the remarks made refer to fractional horsepower motors, it is anticipated that as this type of protector application becomes more accepted, the field of application will spread to integral-horsepower and polyphase motors.

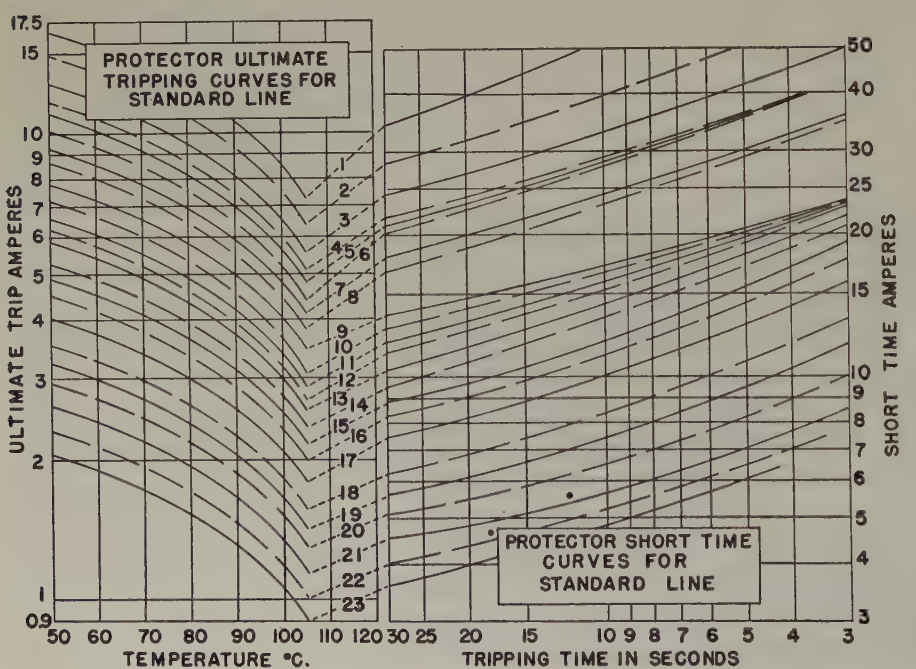

Figure 1. A standard line of protectors is being developed with ultimate-tripping and short-time characteristics indicated by these curves

International Transformer Standards and Applications

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This review discusses the more important differences between various national standards and the International Electrotechnical Commission specifications. There is a decided need for unified international standards or "conversion factors" to equate existing standards.

THERE IS at the present time, and there will be for many years to come, the greatest demand for electric equipment in history throughout the world. The devastations of World War II, the overloading of equipment during the war and since, and the general lack of normal maintenance and replacements have all contributed to this demand. From a global standpoint, the prospects for world exchange of goods, and for our present consideration, electric equipment, were never greater. In such world exchange, the need for more reliable methods for comparing and evaluating bids and products must be obvious. In view of the plans for meeting this fall in London, England, to consider bringing the International Electrotechnical Commission specifications for transformers published in 1939 up to date, the publication of this article is very timely. The article compares the practices of various national standards and suggested revisions and adoption of new material to bring the IEC specification more nearly in line with present-day practices. It is the hope of the authors that this material will be of some aid to those participating in the London meeting.

When, however, comparisons and evaluations of transformers are attempted, it is found that there exist a number of national standards which differ to a greater or lesser degree from each other and from the IEC specifications. Establishment of identical standards throughout the world would be a perfect solution, from an academic standpoint, but there are many factors such as application, usage, economics, and geographic and climatic conditions which make it impractical. However, it does seem reasonable that a sustained co-operative effort could result in a reduction in these differences and in the development of a set of yardsticks whereby the standards of one country could be compared to the standards of another country and expressed in definite numerical relationships. If this can be done, necessary differences in frequencies, voltages, or kilovolt-ampere ratings will not be serious obstacles to fair and careful comparisons and bid evaluation.

Furthermore, careful examination of the IEC and various national specifications indicates the need for clarification in a number of places. It is quite possible that within a given country, or within the confines of its normal trading areas, certain practices through tradition have been generally understood. However, it is obviously desirable to expand or clarify details which can not be clearly understood by all. One of the purposes of this article is to point out those cases where further explanation or modifications in the interest of clarity are desirable.

Another and major purpose of the authors is to discuss important differences between various national standards (some of which seem to be available in rather incomplete and older editions) and the IEC specifications. In some of the more important cases, the American Standards Association standards and practices will be explained in some detail and the reasons for their adoption will be given.

KILOVOLT-AMPERE RATING STANDARDS

The kilovolt-ampere rating that may be assigned to a given transformer depends on the permissible currents and voltages of the windings, and these in turn are found to depend primarily on the permissible temperature rise of the windings and on their ability to withstand standard dielectric strength tests, respectively. Secondarily, the kilovolt-ampere rating depends also on whether it is based on the input or the output of the apparatus, and the power factor of the standard load. Thus, one and the same apparatus will be credited with a different kilovolt-ampere rating depending on specified standards with respect to temperature rise, dielectric tests, load power factor, and so forth. In fact, the IEC specifications recognize two different kilovolt-ampere ratings for the same apparatus.

Comparison of Kilovolt-Ampere Rating Standards Based on Rated Currents and Voltages. One of the factors which complicates the calculations of the kilovolt-ampere rating of a transformer is its per cent voltage drop under load, and this is allowed for differently by different standards.

According to the ASA standards, the apparatus must be capable of delivering simultaneously the voltage and kilovolt ampere ratings shown on its rating plate. If the output voltage tends to drop under load (as it generally does), then the apparatus must be suitable to withstand continuously increased primary excitation to deliver its rated secondary voltage at full rated kilovolt-ampere at 80 per cent power factor.

The IEC standards on this point are not entirely clear to the authors, but the impression is that the official kilovolt-ampere rating of the apparatus shall be calculated based on

Essential substance of a paper presented at the conference on international standardization during the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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Table I. Temperature Rise Limits of Transformers With Different Types of Cooling

Type	Oil Circulation	Cooling	ASA	BSS	ASS	IEC	IEC*	ASE	ASE†	French Wartime (C-325G)
			Class A Insulation Windings, Average Rise by Resistance, C							
Dry		Air-natural	55	55	55	55		55	65	60
		Air-forced								
Oil-immersed	Natural	Air-natural	55	60	55	60	55	60	70	70‡
		Air-forced								70‡
		Water			65	60	55	60	70	70‡
Oil-immersed	Forced oil	Air-natural		65						
		Air-forced	55	65		65	60	60	70	70‡
		Water	55	70	65	65	60	60	75	70‡

* Recommended for continuous operation for an indefinite period.

† No information is available as to whether these wartime standards have been rescinded or are still in effect.

‡ It is understood that the present practice is to use 60 degrees centigrade rise for oil-immersed transformers.

the no-load voltage of the secondary winding multiplied by the rated current of the winding. If the primary winding is excited at its rated (no-load) voltage, then the output voltage at full load will be less than the rated voltage, and the output kilovolt-amperes will be correspondingly reduced. The order of magnitude of this reduction in output may be estimated by assuming about 7 per cent reactance, 1 per cent resistance, and 80 per cent power factor, yielding a little over 5 per cent voltage regulation. The guaranteed kilovolt-ampere output of the IEC-rated transformer then will be 5 per cent less than its official (IEC) kilovolt-ampere rating under this condition. This reduced output is called by the IEC the "service rating" of the apparatus, and may be separately marked on a service-rating plate on the apparatus.

The British Standards call for the "no-load service voltage" to be shown on the rating plate, and the full load current of a winding is defined as "that current which, when multiplied by the voltage marked on the rating plate . . . gives the rated kilovolt-amperes. . . ." This then is the same as the IEC standards.

The Australian Standards are more particular and consistent in this matter, specifying that the apparatus shall "carry its steady non-inductive rated load continuously, without exceeding the temperature rise given in Section VI, when the primary service voltages at the rated frequency, are applied to the primary winding . . ." (clause 28). Taking the "rated load" to mean the rated kilovolt-amperes, it follows that a transformer with Australian Standards Society rating will deliver its rated kilovolt-amperes at least at unity power factor, permitting its output current to be increased sufficiently to compensate for the drop in voltage. As the voltage regulation at unity power factor is generally small—about 1.25 per cent in the foregoing example—this rule does not constitute a serious hardship on the apparatus, while it justifies with very good grace the kilovolt-ampere rating credited to the apparatus on its rating plate.

The latest French rules on this point are not known to the authors.

TEMPERATURE BASES

The permissible temperature rises recognized by the different standards known to the authors are shown in Table I.

It will be seen here that the IEC, BSS (British), ASS (Australian), and French wartime standards specify from 5 to 15 degrees higher rises than the ASA rise of 55 degrees centigrade. As the 70-degree-centigrade rise is specified only for water cooling by the BSS standards, this means that in the majority of cases the difference between the ASA and the others is five to ten degrees centigrade. (Note: Although the French wartime standards specify 70 degrees centigrade rise for all transformers, it is understood that the present practice is to specify 60 degrees centigrade rise.) In order to compromise this difference, it appears reasonable for the ASA to give consideration to increasing by five degrees centigrade the temperature rise for two classes of transformers, namely, the water-cooled and forced-oil cooled types.

Water-Cooled Transformers. A leeway of five degrees centigrade is maintained in the ASA rules for water-cooled

Table II. Dielectric Test Standards

E Designates the Service Voltage in Kilovolts Between Lines

	ASA	BSS	IEC	ASE	Sweden Sept 30, 1944	Italian and Swiss Proposals	ASS
Applied voltage test							
Neutral not grounded	$2E$*	$1+2E$	$1+2E$				
Neutral grounded	$2E$ or less†	$1+1.6E$	$1+2E$‡ $1+1.6E$**				
Induced voltage test							
Neutral not grounded	$2E$	$2E$	$2E$	$2E$			
Neutral grounded	$2E$ or less[a]	$1+2.8E$[b] $1+3.46E$[b]	$2E$[c]	$2E$[c]			
Impulse voltage test							
Neutral not grounded	See Fig 2[d]	None	None		See Fig 2	See Fig 2	None
Neutral grounded	See Fig 2[d,e]	None	None		None	None	None

* For 25 kv or more—$2E$ rounded out to the nearest 5-kv test. For 15 kv or less:

Circuit Kv	ASA Test Kv
15	34
8.7	26
5.0	19
1.2	10

† Depending on the impedance used between the transformer neutral and ground.

‡ Up to 80 kv.

** More than 80 kv.

[a] Where the induced voltage test replaced the applied voltage test, the value of the induced test is such as to stress the line-to-line terminals equal to that required in the standards for the insulation class chosen. See [e] for practice sometimes followed in choosing a lower than standard insulation class.

[b] This test, if made 3-phase, requires an unnecessarily large spacing between the bushings of 3-phase transformers. The ASA overcomes this difficulty by permitting a single-phase connection on 3-phase units with special connections producing twice line-to-line voltage between the bushings and 2.3 times normal voltage from line to neutral. The BSS $1+3.46E$ test applies to transformers for use in lightning areas.

[c] Except with graded insulation and with neutral directly grounded. Up to 80 kv, the test voltage equals $1.73+3.46E^b$. More than 80 kv, the test voltage equals $1.73+2.77E^b$ with a minimum of 279 kv.

[d] Although impulse strength levels have been established for all voltage ratings, the impulse testing is optional with the user. Up to the present time, only a small percentage (five to ten per cent) of all transformers have been impulse-tested.

[e] Can be lower. The practice of purchasing an insulation level one step below that corresponding to the voltage rating often is used where adequate impulse protection can be provided (by lightning arresters). This practice appears to be on the increase in North America.

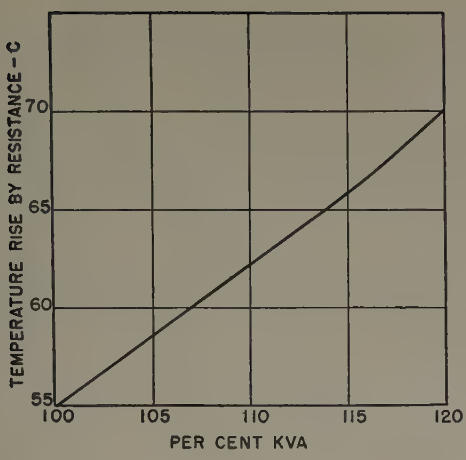

Figure 1. Conversion curve for comparing kilovolt-amperes of oil-immersed transformers with different temperature rises

Approximate rule: 1.4 per cent kilovolt-ampere change per degree centigrade change in rise

transformers (where the cooling water is 25 degrees centigrade as against 30 degrees centigrade for air) to allow for possible increase in the oil temperature because of impairment of efficiency of the cooling coils. As improved means are available today for detecting increases in temperatures under operating conditions such as hot-spot temperature indicators and more reliable oil thermometers, it would seem that the temperature rise of water-cooled transformers could be safely increased from 55 to 60 degrees centigrade. The number of water-cooled transformers built during the past few years has been relatively small, and this method of cooling seems to be on the way out.

Forced-Oil-Cooled Transformers. Consideration should be given by the ASA to permit five degrees centigrade higher average rise in forced-oil-cooled transformers than in those cooled by natural oil flow, as is now incorporated in most other national standards. This proposal is based on the assumption that with forced-oil cooling it is practical to design a transformer for a hot-spot temperature not over five degrees centigrade above the average winding temperature. This keeps the hot-spot temperature unchanged.

If the average winding temperature rise for these two classes of transformers is increased by five degrees centigrade by the ASA, bringing it up to 60 degrees centigrade, this will be a logical step towards bringing the temperature rise of transformers in various national standards closer together.

CONVERSION FACTORS FOR REDUCING THE RATING IN ANY ONE STANDARD TO THE RATING IN ANOTHER STANDARD

Figure 1 gives a conversion curve for comparing the kilovolt-ampere ratings of oil-immersed transformers for various temperature rises from 55 to 70 degrees centigrade. It will be noted that the kilovolt-ampere rating changes approximately 1.4 per cent for each degree centigrade change in the average temperature rise by resistance, or, approximately 7 per cent for each 5-degree change in temperature rise.

DIELECTRIC TESTS

Dielectric tests are divided into three kinds:

1. Applied voltage tests.
2. Induced voltage tests.
3. Impulse voltage tests.

The rules governing these tests under various standards are shown in Table II.

It is interesting to note that, with the neutral grounded, the ASA Standards require an induced voltage test of $2E$ (and there is a noticeable trend toward lower values where adequate lightning protection is provided at the transformer terminals), whereas the BSS and IEC with graded insulation specify a test greater than $2E$. Perhaps the reason for these diametrically opposed practices is that the ASA tests are based on protection against lightning stresses, whereas the BSS and IEC tests are based on protection against expected operating frequency stresses. The reason for this difference in practice needs some clarification.

It appears desirable that impulse levels be adopted internationally for various voltage classes.

TOLERANCES

The tolerance on losses, voltage ratio, impedance, and no-load current in ASA and other available national standards, as well as in IEC, are exhibited in Table III.

Differences in tolerances between various standards produce difficulties in the evaluation of bids. For example, consider the matter of losses.

Assume transformer A is on the basis of the ASA practice and transformer B in accordance with the IEC specification. In the case where several units were being bid, the tolerance on the no-load loss, according to the ASA practice, would be zero for the average of the units but would be ten per cent according to the IEC practice.

Because it is a practical impossibility for final measured

Table III. Comparison of Transformer Tolerances

All Numerical Values Are in Per Cent

	ASA	IEC	BSS	ASS	ASE*
Voltage ratio at no load	1/2	1/2 or 1/10 of per cent IZ at rated load whichever is less	Same as IEC	Same as IEC	Same as IEC
Losses					
No-load loss					
One unit, single-phase	10	10	10	10	14.2
One unit, 3-phase	0	10	10	10	14.2
Two units or more					
Average	0	10	10	10	14.2
Individual units	10	10	10	10	14.2
Impedance loss		10	10	10	14.2
Total losses					
One unit, single-phase	6	10	10	10	10
One unit, 3-phase	0	10	10	10	10
Two units or more					
Average	0	10	10	10	10
Individual units	6	10	10	10	10
Efficiency	Governed by the tolerances on losses	Same as ASA	Same as ASA	Same as ASA	Same as ASA
Impedance voltage					
2-winding unit	7.5	10 (10+ for complicated cases)	10 for main taps, 15 for others	10	10 for main taps, 15 for others
3 windings or more	10				
Zigzag windings	10				
Autotransformers	10				
No-load current	No tolerance established	30	No tolerance established	30	30
Per cent voltage drop	Governed by tolerance on losses and voltages	Same as ASA	Same as ASA	10, more when IZ exceeds 10 per cent	Same as ASA

* ASE publication 108, 108a, and 108bf.

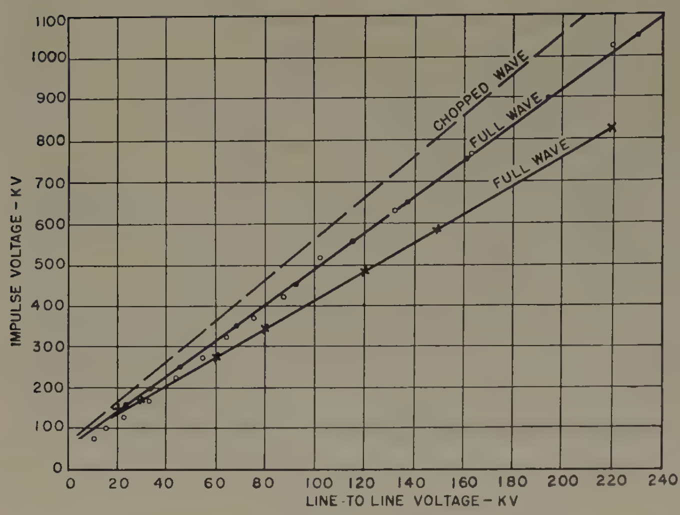

Figure 2. Comparison of impulse voltage tests either in use or under consideration for transformers

- - *ASA*
● *ASA*
○ *Sweden, Sen 30, 1944. Generator or sending end of line kilovolts are given. Voltage at receiving end of line is ten per cent lower*
× *Italian and Swiss proposals*

characteristics to be exactly in line with the designers' calculations, the designer of transformer *A* actually must design a unit with lower core losses than covered by the bid specifications. This provides a factor of safety sufficient to insure that the average will meet the bid specifications. On the converse, the designer of transformer *B* can design his unit right up to specifications, even slightly over, being fully protected by the ten per cent permissible margin. To place a numerical value on the difference between *A* and *B* units is difficult. The average *A* transformer might test right up to warranty but no better; the average *B* transformer might meet the warranty without its ten per cent tolerance. In such infrequent cases the two would be equal. Yet is it obvious that the average of transformers *A* will run consistently lower in core loss than the average of transformers *B*.

Table IV. ASA Standards for Loading on Basis of Ambient Temperature

	Per Cent of Rated Kva	
Type of Cooling	Decrease Load for Higher Temp	Increase Load for Lower Temp
Self-cooled	1.5	1.0
Water-cooled	1.5	1.0
Forced-air-cooled	1.0	0.75
Forced-oil-cooled	1.0	0.75

Table V. ASA Standards for Loading on Basis of Load Factor

Type of Cooling	Increase in Per Cent of Rated Kva	Maximum Per Cent Increase*
Self-cooled	0.5	25
Water-cooled	0.5	25
Forced-air-cooled	0.4	20
Forced-oil-cooled	0.4	20

* Corresponds to 50 per cent load factor.

The warranted core losses on the specification might be identical and compared accordingly, leading to deceptive conclusions.

The same situation exists with total losses. The situation is less clear with respect to voltage ratio and impedance voltage tolerances but it seems clear that transformers built to a smaller permissible tolerance in these characteristics will tend to cost more than where the tolerance is greater.

From this discussion it would seem that numerical comparison ratios are hardly practical with respect to tolerances. However, there would seem to be no practical barrier to the adoption of a universal practice with respect to this phase of the Standards.

In general, it would seem that universal tolerances on losses, impedance, and other guaranteed performance could be chosen to reflect normal design margins so that the average test performance would be close to the warranty but the odd transformer that might happen to test on the high side would not be rejected.

LOADING OF TRANSFORMERS UNDER VARIABLE LOAD AND AMBIENT TEMPERATURE CONDITIONS

In addition to the rating standards, which serve to establish those characteristics which form the contractual basis for commercial transactions, the ASA Standards contain guides for the operation of transformers to facilitate intelligent usage under the conditions of varying loads and ambient temperatures encountered in the majority of applications. The BSS and ASS Standards contain information of similar nature, differing, however, both in the scope of conditions covered and in the magnitudes of the loading values. In considering the relative values given in the following comparison it is important that the differences in the bases of rating, previously discussed, be factored.

Guides for Loading. Tables IV, V, VI, and VII are taken from the ASA guide which is to be published in the near future with the revised ASA Standards.

The British Standard Specification gives basic duration of overloads in minutes for a time constant of one hour for different types of transformers in ambient temperatures from 20 to 45 degrees centigrade, and the multiplying factor

Table VI. ASA Standards for Permissible Daily Overloads to Give Normal Life Expectancy

Ambient Temperature Is Assumed to Be 30 Degrees Centigrade for Air and 25 Degrees Centigrade for Water

	Initial Load, Per Cent*								
	90	70	50	90	70	50	90	70	50
Time, Hr	Self-Cooled and Water-Cooled Transformers			Forced-Air-Cooled Transformers Rated 133 Per Cent or Less of Self-Cooled Rating			Forced-Air-Cooled Transformers Rated More than 133 Per Cent of Self-Cooleo Rating and All Forced-Oil-Cooled		
1/2	1.59	1.77	1.89	1.45	1.58	1.68	1.36	1.47	1.50
1	1.40	1.54	1.60	1.31	1.38	1.50	1.24	1.31	1.34
2	1.24	1.33	1.37	1.19	1.23	1.26	1.14	1.18	1.21
4	1.12	1.17	1.19	1.11	1.13	1.15	1.09	1.10	1.10
8	1.06	1.08	1.08	1.06	1.07	1.07	1.05	1.06	1.06

* Percentages fix the load which is assumed to exist before the short-time load is applied. Use either average load for two hours previous to load above rating or average load for 24 hours (less overload period), whichever is greater.

for different kilovolt-ampere and voltage ratings having time constants ranging from one to five hours.

Table VIII gives the recommended overloads following full load for self-cooled (type *ON*) transformers 1,001 to 10,000 kva with their associated time constants with 20 degrees centigrade daily average ambient temperature. Similar overloads are permitted for other types of transformers, the time varying depending on the method of cooling used and the initial loading conditions.

The Australian specification provides several tables for overloading under various conditions. In general, these permit larger overloads or longer durations than the British guide. Table IX is reproduced here as illustration. This table involves small unstated sacrifices of life expectancy because it permits the overloads to follow full-load conditions at standard ambient temperatures. However, these loadings are very much less than the ASA figures given in Table VII for a loss of not over one per cent of the life expectancy.

Although overloads are not recognized in the French wartime standards, the subject of the choice of electrical materials from the standpoint of their heating properties is discussed at length in a comprehensive report[10] by Langlois-Berthelot, and a paper presented at the 1946 session of the Conference Internationale de Grandes Réseaux Electriques à Haute Tension, Paris, France, by Langlois-Berthelot and M. Laborde. These articles indicate that the electrical industry in France is becoming greatly interested in the possibilities of loading electric apparatus by its ability to withstand temperatures rather than by the name plate rating.

There are no IEC, Swedish, and Swiss guides for the overloading of transformers under variable load conditions.

Ambient Temperatures. The ambient temperatures recognized in the various standards are shown in Table X.

RECOMMENDATIONS

Obviously much study must be given the subject of unified international standards by joint groups thoroughly familiar with the various standards and the reasons leading to their adoption. It therefore is recommended that the IEC and various national representatives thereon give careful consideration to the following suggestions:

1. To reconcile the various national standards and practices to the maximum practical extent, with the final goal of having all national standards and practices eventually conform to IEC specifications.

2. To clarify any items of difference which still remain, and state the reasons for the divergence.

3. Where a universal standard is not adopted, to agree on conversion factors to convert one national standard to another by a definite numerical factor so that intelligent comparison and evaluation of bids can be made when purchasing and selling in world markets.

Table VII. ASA Standards for Short-Time Loading With Moderate Sacrifice of Life Expectancy, Self-Cooled and Water-Cooled Transformers

Following 100 Per Cent of Rated Kilovolt-Amperes or Top-Oil Temperature Rise of 45 Degrees Centigrade. Ambient Temperature 30 Degrees Centigrade for Air, 25 Degrees Centigrade for Water

	Times Rated Kva for Loss of Not More Than Following Life, Per Cent			
Time, Hr	0.1	0.25	0.50	1.0
1/2	1.75	1.92	2.00	2.00
1	1.54	1.69	1.81	1.92
2	1.35	1.48	1.58	1.68
4	1.20	1.32	1.40	1.48
8	1.11	1.20	1.28	1.35
24	1.05	1.09	1.15	1.23

Table VIII. BSS Recommended Overloads Following Full Load With 20 Degrees Centigrade Daily Average Ambient Temperature

	Duration, Minutes			
Overload, Per Cent	11,000 V*, 2†	33,000 V*, 2.25†	66,000 V*, 2.5†	110,000 V or More*, 3.0†
10	Continuous	Continuous	Continuous	Continuous
20	80	92	100	120
30	30	34	37	45
50	10	11	12.5	25
75	5	5.7	6.2	7.5
100	2	2.25	2.5	3

* High-voltage rating. † Time constant in hours.

Table IX. Australian Guide for Overloading

	Overload*, Per Cent	Time, Hr
Oil-immersed, natural cooling	10	7
	20	2 1/4
	30	1
	50	1/2
	75	1/6
	100	1/30

* Following full load in cooling air not exceeding 35 degrees centigrade.

Table X. Ambient Temperatures Recognized by the Various Standards

	ASA	BSS and IEC	Swiss, Swedish, and French
Air			
Daily max, C	40	40	40
Daily avg, C	30	35	
Water			
Daily max, C	30	25	25
Daily avg, C	25	25	

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The Electrostatic Generator Used in Nuclear Studies

W. E. SHOUPP

Although other accelerators can produce higher voltages, the Van de Graaff generator is still the work horse of nuclear physics because of the greater precision which it enables.

NUCLEAR PHYSICS has progressed to a point where the term "million electron volts" is considered to be a small unit, and the size of nuclear accelerators and the number of volts obtained from them is limited only by the size of one's pocketbook. Indeed some nuclear physicists use a new unit in their language; and that unit the "megavolts per kilobuck" has a very real meaning. Many laboratories are constructing or operating machines in the 100 to 400 million electron volt range and plans are being made for the construction of accelerators in the one to three billion electron volt range. At present there are roughly 25 cyclotrons, 10 synchrotrons, 8 electrostatic generators, 15 betatrons, 6 linear accelerators, and a few other machines of miscellaneous types in operation or under construction.

The larger cyclotron will accelerate deuterons to some 20 million electron volts and the upper limit for the energy of the frequency modulated or synchro-cyclotron (dictated largely by economics) seems to be somewhat less than 400 million electron volts. The characteristics of the cyclotron and synchro-cyclotron are very high voltage and high current output and quite efficient operation from a power standpoint. Indeed the University of Pittsburgh, Pittsburgh, Pa., cyclotron gives 150 microamperes deuterons at 18 million electron volts for an input power of 17 kw, these data give an efficiency of some 15 per cent which is a very respectable figure indeed. It is possible, in the million-volt region, to get more volts and indeed more watts in the positive ion beam, per dollar, with the cyclotron than with machines of other types. Consequently cyclotrons are of particular value for the efficient manufacture of certain radioactive isotopes that are not easily obtainable from nuclear reactors, and for the study of nuclear processes that do not occur at lower voltages. Examples of experiments of this type are investigations concerning the fission of elements lower in the periodic table than thorium, the production of very high energy neutron or positive ion beams for physical and therapeutic purposes and physical experiments, and the production of multiple particle disintegrations.

The betatron is similar to the cyclotron in that considerable voltage is obtained in a small physical volume and for a reasonable cost. In the betatron, electrons are accelerated and the relativistic variation in mass does not plague the user as would be the case if he tried to accelerate electrons in a cyclotron. Betatrons that accelerate electrons to 2, 4, 20, and 100 million electron volts are in use and one designed to operate at 300 million electron volts is under construction. X rays (or should I say gamma rays) of course are generated if the electrons are allowed to strike tungsten targets and these radiations as well as the accelerated electron beam may be used for scientific purposes.

The synchrotron principle may be used to accelerate either electrons or heavier particles and is particularly economical, for voltages of more than 300 million electron volts.

All of the magnetic accelerators, though their voltage and currents are relatively high, have four disadvantages:

1. The beam is difficult to remove from the target chamber.
2. The background radiation is usually high.
3. The beam is generally not monoenergetic.
4. It is difficult to vary and control the energy of the beam continuously.

For these reasons, when one does certain precision nuclear measurements such as threshold reaction studies, scattering experiments, or cross section work, magnetic machines generally are not used unless it is absolutely necessary. The electrostatic generator, invented in 1931 by R. J. Van de Graaff, has unusual aptitudes for experiments of just these types. In fact this machine has been termed the "work horse" of nuclear physics. I believe that more precise studies of nuclear reactions and nuclear forces have been done by the use of the electrostatic generators than with all other types of accelerators combined. The electrostatic generators of present design do not deliver particularly high voltage nor are high currents generally possible. Five million volts seems to be a top value obtainable at the moment, and a few microamperes of resolved positive ions is a good round number for the currents obtained. The machine is usually fairly large, in fact, the Westinghouse generator (Figure 1) stands some 47 feet high and weighs about 100 tons, and has been called the world's biggest 7-watt vacuum tube. What, then, are the characteristics of the electrostatic generator that make it so valuable? In machines of this type, the beam is accelerated along a straight line and so no problems are encountered in positioning targets and measuring apparatus within and about the beam. The positive ion beam is generally well focussed and has little opportunity to strike surfaces elsewhere than at the target so that a low radiation background is attained.

THE NUCLEAR ENERGY SCALE

The electrostatic generator is a d-c machine. The full acceleration voltage is generated and this voltage may be

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measured accurately and regulated easily or changed by small or large voltage steps. The beam obtained from a hydrogen ion source has generally three components or rather, three types of hydrogen ions; they are, H^+, HH^+ HHH^+. At first glance these individual beams might appear to be a serious disadvantage, however, they are a blessing in disguise. Each of the three types of ions are singly charged and are accelerated through the same potential difference and easily are separated into individual spots at the target chamber. For a particular ion, the energy is split equally between the protons comprising the particular ion. Now if a nuclear threshold or some calibrated voltage point is obtained with the H^+ beam, it will take twice or three times the voltage to cause the same nuclear reaction to occur with the HH^+ or HHH^+ beam respectively. This means that if there is a voltage calibration point at one million volts, by using the mass 2 (HH^+) or the mass 3 (HHH^+) spot, the voltage is calibrated at two or three million volts to the same accuracy.

The absolute voltage scale was calibrated at about one million volts by measuring the current through a corona-free resistor and this value is or has been extended to about three million volts by use of the mass 3 spot, however, the errors in absolute voltage at three million volts may be as much as one per cent, although relative voltage measurements regularly are made to better than 0.1 per cent accuracy. This means that the whole voltage scale, that is so important to nuclear physics, may be off by as much as one per cent. It is consequently very desirable to establish a better absolute voltage calibration.

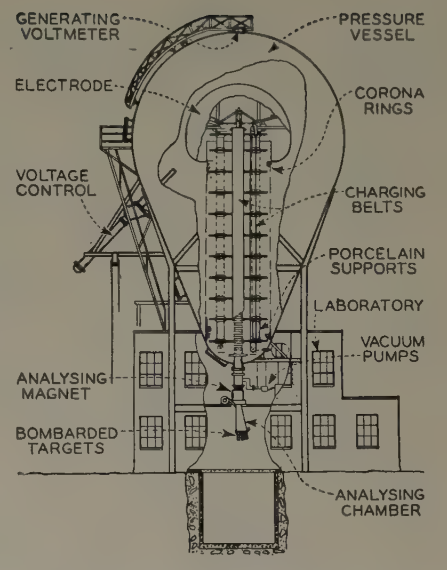
THE RADIO-FREQUENCY ION SPEED GAUGE

A radio-frequency method has been developed at our laboratories that appears to be capable of performing this function. If a beam of particles is amplitude-modulated by a well-established frequency f and allowed to enter a resonant cavity composed of two concentric cylinders (Figure 2) oscillations will be built up because of the beam crossing gap A provided that the natural frequency of the cavity is equal to the modulation frequency. Now if the same beam emerges from the cavity after a time equivalent to that required for an odd number of half cycles n of the modulation frequency to occur, the oscillation built up because of gap B will cancel or diminish that of gap A. There are, of course, restrictions on many of the parameters involved such as the Q of the cavity and gap dimensions; however, it easily is seen that at the minimum of radio-frequency excitation of the cavity, the voltage of the particles is given by

$$V=\frac{2mf^2l^2}{e\;\;n^2}$$

where m is the mass number of the particle, l is the length of the cavity, and e is the voltage. To check the performance of such a system we have set up such a device and have used a modulated electron beam instead of positive ions, thereby enabling us to use only a few thousand volts for acceleration, instead of a few million as would be required for positive ions. Using this method it has been shown to be possible to measure the velocity of a one microampere beam to

Figure 1. The Westinghouse electrostatic generator



better than 0.1 per cent and we anticipate no difficulty in using the same cavity for the velocity measurements of the ion beam in our electrostatic generator for voltage calibrations up to at least four million volts. When these experiments are completed, it will be possible to revise the energy threshold values at which nuclear reactions occur and the whole nuclear voltage scale will be known to a considerably greater accuracy.

DETERMINATIONS OF ISOTOPIC MASS FROM THRESHOLD DATA

The question may be asked "What nuclear experiments require such a well-known nuclear energy scale?" The answer to this question is far too complex to consider in detail here, however I will describe certain nuclear experiments using these accuracies. If the nuclear reactions are considered for an element A, having atomic number or nuclear charge Z, and mass number m, when it is bombarded by protons (${}_1H^1$), it is seen that frequently neutrons (${}_0n^1$) are emitted and that a new element B is formed.

$${}_ZA^m+{}_1H^1\rightarrow{}_{Z+1}B^m+{}_0n^1+Q$$

In general for reactions of this type, energy is required. that is the energy balance term Q is negative, and the reaction is said to be endoenergetic. If Q can be measured accurately, and the mass is known of any three of the four particles involved (A, ${}_1H^1$, B, ${}_0n^1$) the mass of the fourth is determined. The energy balance or reaction energy Q is obtained by measuring the voltage or energy of the bombarding particle (${}_1H^1$) that is just sufficient to cause the reaction to take place. This energy is called the threshold energy E_t and from the conservation of momentum and energy it is possible to derive the equation

$$Q=-\left(\frac{m}{m+d}\right)E_t$$

where m is the mass number of the target element and d is the mass number of the bombarding particle which in this case, for the proton, is one. This equation applies only to endoenergetic reactions and for simple disintegration types. A typical set of experimental data for the determination of the threshold of ${}_{29}Cu^{65}$ is shown in Figure 3. From these data it is easy to determine the threshold energy to about 0.5 per cent. From the nuclear reaction that occurs, namely

$${}_{29}Cu^{65}+{}_1H^1\rightarrow{}_{30}Zn^{65}+{}_0n^1+Q$$

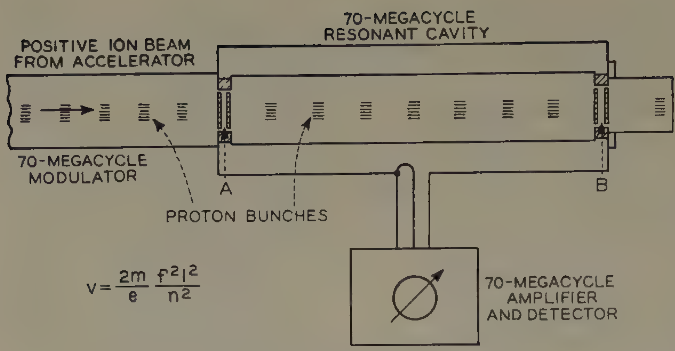


Figure 2. Resonant cavity

which may be written,

$$({}_{29}Cu^{65}-{}_{30}Zn^{65})=({}_0n^1-{}_1H^1)+Q$$

the mass difference $(Zn^{65}-{}_{29}Cu^{65})$ easily is determined to be 1.376 million electron volts because the mass difference $({}_0n^1-{}_1H^1)$ is known to be 0.755 million electron volts and Q has been determined, from our measurements of E_t, to be (−2.131 million electron volts). In this instance the mass of ${}_{29}Cu^{65}$, (64.955 mass units) is taken from mass spectrographic data consequently, the mass of ${}_{30}Zn^{65}$ is calculated to be 64.8565 mass units to an accuracy of 0.01 per cent.

MAXIMUM ENERGY OF BETA-RAY SPECTRA

The zinc isotope ${}_{30}Zn^{65}$ formed in this reaction is radioactive and it is now possible to compute the maximum energy of the positrons to considerable accuracy, that emerge from ${}_{30}Zn^{65}$. The radioactive zinc isotope ${}_{30}Zn^{65}$ decays to stable ${}_{29}Cu^{65}$ through the following process:

$${}_{30}Zn^{65}\rightarrow{}_{29}Cu^{65}+\beta_++2m_e$$

or

$$\beta_+=({}_{30}Zn^{65}-{}_{29}Cu^{65})-2m_e,$$

where β_+ is the maximum energy of the positrons given off, m_e is the electronic mass. Using the values as determined in our measurements we have

$$\beta_+=1.376-1.021=0.355 \text{ million electron volts}$$

Thus the value of the maximum accuracy of the positron spectrum (β_+) of ${}_{30}Zn^{65}$ is determined to considerable accuracy compared to previous determinations by other methods.

From further threshold experiments on other experiments of the (p,n)—proton projectile, neutron emission-type—the masses which have been obtained are shown in Table I.

Table I. Determination of the Masses by (p, n) Threshold Experiments

Target Element	Reaction	Mass, Mass Units	Of Element	E_t, Million Electron Volts	Q, Million Electron Volts
${}_3Li^7$	${}_3Li^7\ (p,n)$	7.01908 ±0.00011	${}_4Be^7$	1.85 ±0.02	1.62 ±0.02
${}_4Be^9$	${}_4Be^9\ (p,n)$	9.01600 ±0.00013	${}_5B^9$	2.03 ±0.01	1.83 ±0.01
${}_5B^{11}$	${}_5B^{11}\ (p,n)$	11.01499 ±0.00020	${}_6C^{11}$	2.97 ±0.01	2.72 ±0.01
${}_6C^{13}$	${}_6C^{13}\ (p,n)$	13.01004 ±0.00015	${}_7N^{13}$	3.20 ±0.03	2.97 ±0.03

Because mass differences are measured in the determination of the reaction energy thresholds, that the resulting mass values are obtained very accurately indeed.

VARIABLE ENERGY NEUTRON SOURCES

It is frequently of importance to determine the neutron energy threshold required to produce a particular reaction. As neutrons are not electrically charged, they are not capable of being accelerated by electric machines. However, when neutrons are produced in a nuclear reaction they are emitted at the various angles from the target, with corresponding variable energies as governed by the conservation of momentum—the forward direction obtaining a greater fraction of the momentum of the incident bombarding particle and those emitted at right angles receiving none of this momentum.

In general the energy of the emerging particle (E_2) is given by

$$(M_2+M_3)E_2^{1/2}=(M_1M_2)^{1/2}E_1^{1/2}\cos\theta+\{[(M_2+M_3)M_3Q]+(M_0M_3E_1)-(M_1M_2E_1\sin^2\theta)\}^{1/2}$$

where M_0, M_1, M_2, M_3, E_0, E_1, E_2, and E_3 refer to the masses and energies of the initial nucleus, the bombarding particle, the produced particle, and the produced nucleus respectively. The value of Q refers to the energy required for the process to occur, and θ is the angle of emission of the produced particle M_2. In the forward direction of the bombarding particle $\theta=0$, the energy of the emitted particle is

$$E_2^{1/2}=\frac{(M_1M_2)^{1/2}}{M_2+M_3}E_1^{1/2}+\frac{M_3^{1/2}}{M_2+M_3}\{(M_2+M_3)Q+M_0E_1\}^{1/2}$$

If a machine is capable of accelerating ions to 3 million electron volts, neutrons from a target of ${}_3Li^7$ may be obtained having energies as high as 1.30 million electron volts by bombarding the ${}_3Li^7$ with protons of three million electron volts. For a thick target the neutron energy will have a continuous distribution from a low value of 0.20 to a maximum of 1.3 million electron volts (for three-million electron volts protons). If a thin target is used, monoenergetic neutrons are available for any energy within this range depending on the energy of the protons.

With a variable energy neutron source available it is possible to study the threshold of endoenergetic neutron induced reactions in the same manner as the (p,n) thresholds were studied with the variable energy proton beam. Other energy ranges are likewise possible depending upon the particular reaction used and the voltage applied to the accelerator. By this means thresholds of reactions of the (n,p),

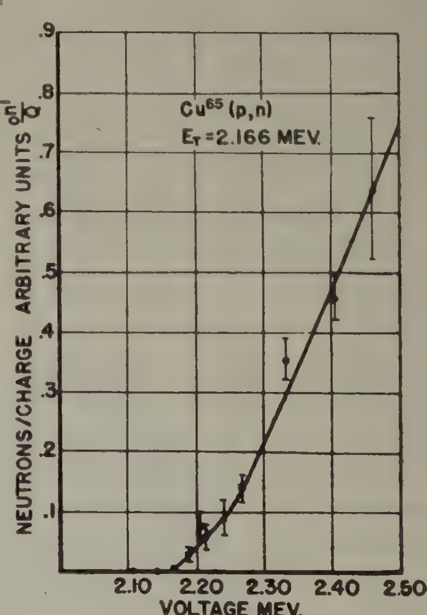


Figure 3. Neutrons per charge versus voltage

(n,d), (n,α) type may be determined and from the Q thus measured, mass data may be obtained.

PHOTODISINTEGRATIONS AND NEUTRON MASS

Electrostatic generators also may be used to accelerate electrons by carrying electrons from ground to the high-voltage electrode to build up a high negative voltage. If the customary ion source is replaced by a filament, electrons may be accelerated down the vacuum tube. When these electrons strike targets placed at the bottom of the vacuum tube, X rays are produced having a maximum energy whose magnitude is equal to the high voltage produced by the machine. If the voltage of the machine gradually is increased, the threshold of nuclear reactions induced by the X radiation may be observed. Many nuclei have been studied by these methods but of singular importance is the disintegration of the heavy isotope of hydrogen, deuterium ($_1D^2$). By bombarding deuterium with the X-ray quanta ($h\nu$) produced by the accelerated electron beam the deuterium has been shown to disintegrate. The threshold of this reaction, in which a neutron and proton are produced, has been observed to occur at 2.187 ± 0.011 million electron volts.

$$_1D^2+(h\nu)\rightarrow{}_0n^1+{}_1H^1$$

From spectrographic data the mass doublet (HH-D) is known to be $1.432\pm.005$ million electron volts and using the threshold data obtained for this reaction the $_0n^1-{}_1H^1$ mass difference now may be computed to be 0.755 ± 0.016 million electron volts which is the value used in the previous computations. Because the mass of the hydrogen atom (1.00813 mass units) is known, the mass of the neutron is computed to be 1.00894 mass units.

THE $_0n^1-{}_1H^1$ MASS DIFFERENCE AND THE MASS OF THE NEUTRINO

Coupled with other data the (p,n) reaction thresholds also may be used in a cycle for a determination of the neutron—hydrogen $(_0n^1-{}_1H^1)$ mass difference. With reference to the equations in "Determination of Isotopic Mass From Threshold Data," the radioactive nucleus $_{z+1}B^m$ usually will decay by the emission of a positron (β^+); thus,

$$_{z+1}B^m\rightarrow{}_zA^m++\beta_+2m_e+\mu$$

where β_+ is the maximum energy of the emitted positron, m_e the electronic mass, and μ is the rest mass of the neutrino. Solving these two equations simultaneously for the $(_0n^1-\text{H})$ mass difference

$$(_0n^1-{}_1H^1)=-\beta_+-Q-\mu-2m_e$$

Using carbon $_6C^{13}$, the (p,n) energy threshold was measured to be 3.20 million electron volts, giving $Q=2.97$ million electron volts. The value of β_+ is known to be 1.198 million electron volts. This gives for the $_0n^1-{}_1H^1$ a value of 0.751 ± 0.03 million electron volts. If the value 0.755 ±0.016 is used for $(_0n^1-{}_1H^1)$ as obtained from the disintegration of the deuteron by X rays, it is possible to calculate certain limits for the mass of the neutrino μ.

$$\begin{aligned}\mu&=-(_0n^1-{}_1H^1)-2m_e-\beta_+-Q\\&=-0.755-1.021-1.198+2.970\\&=0.004\pm.05 \text{ million electron volts}\end{aligned}$$

Thus it can be shown that the neutrino, if it exists at all, as a mass is certainly less than 0.1 the rest mass of the electron.

There are many other reaction chains now being investigated that will lead to more and better results of this type. Endoenergic reactions capable of being studied await only the proper equipment and time for investigation. A tabulation of these reactions for the light elements (deuterium–neon) and their energy balance Q is given in Table II.

Table II. Reactions and Their Energy Balance

Element	Reaction and Q Value (Negative) Prediction or Measurement, Million Electron Volts										
	(p, n)	(n, p)	(n, d)	(n, α)	(α, n)	(d, n)	(d, α)	(p, α)	(α, p)	(n, γ)	(d, p)
$_1D^2$	2.18				2.2						
$_1T^3$	0.7				4.7				7.5		
$_2He^3$			3.2						2.9		
$_2He^4$			17.6		1.9				17		
$_3Li^6$		2.9							2.2		
$_3Li^7$	1.62		7.8		3.8				2.6		1.0
$_4Be^7$			3.4		6.4				1.1		
$_4Be^8$			14.0								
$_4Be^9$	1.83		14.0	0.8					7.6		
$_4Be^{10}$	0.2										
$_5B^{10}$	5.2		4.3								
$_5B^{11}$	2.72		9.0	6.6							
$_6C^{11}$			6.5								
$_6C^{12}$		13.4	14	5.8	8.4	0.3	1.4		5.0		
$_6C^{13}$	2.97		16	4.0				4.1			
$_6C^{14}$	0.6				1.8			0.9			
$_7N^{13}$				0.6				6.4			
$_7N^{14}$			5.4	0.3	4.7			3.0	1.1		
$_7N^{15}$	3.5		8.0	8.5	6.2				4.0		
$_8O^{15}$			5.1						2.7		
$_8O^{16}$			10	2.3	12	1.6		5.3	8.1		
$_8O^{17}$	3.4								5.8		
$_8O^{18}$	2.2				0.8				2.1	0.1	
$_9F^{18}$			3.5		1.9						
$_9F^{19}$	3.8	8.0	3.8		0.4						
$_9F^{20}$			12								
$_{10}Ne^{19}$			4.2								
$_{10}Ne^{20}$		6.4		0.6	6.7			4.2	1.5		
$_{10}Ne^{21}$	4.9		12					3.1	2.5		
$_{10}Ne^{22}$	2.1			9.7	0.4			1.7			
$_{10}Ne^{23}$								0.9			

SUMMARY

Nuclear reaction threshold studies represent powerful means for the measurement of mass differences in nuclear reactions and lead to very accurate mass values and other basic nuclear information. The chief error of such measurements is the calibration of absolute voltage scale. Radio-frequency techniques may assist materially in overcoming this difficulty by offering direct velocity measurements which are independent of nuclear reactions or resistance measurements.

Electric Circuit Models of Partial Differential Equations

GABRIEL KRON
MEMBER AIEE

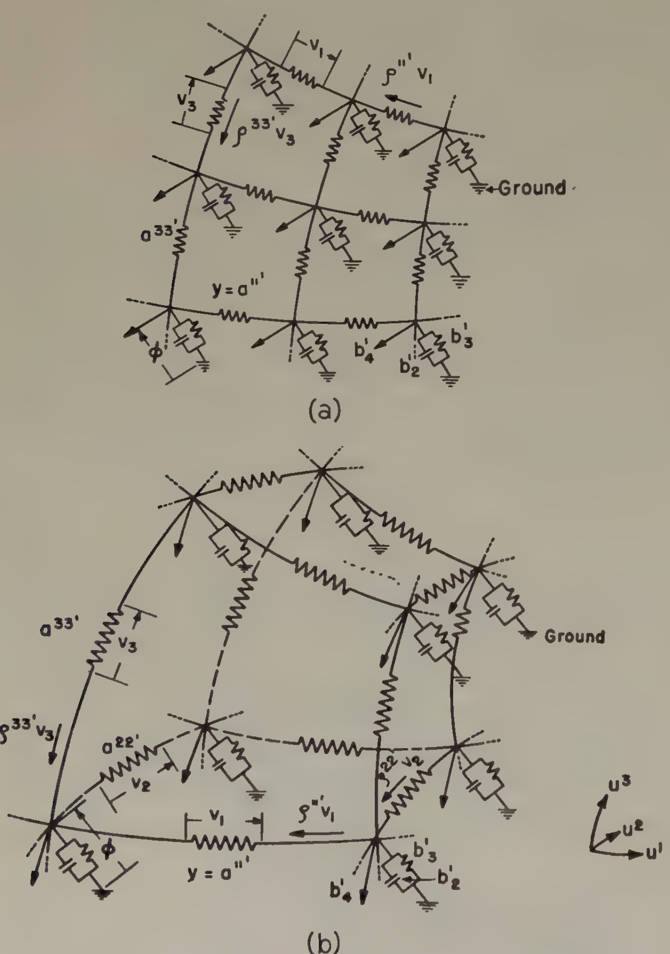
ELECTRICAL MODELS of linear partial differential equations may serve several practical purposes:

1. If the networks are physically constructed, they actually may solve the equations within an accuracy of, say, one to five per cent, which is acceptable in many engineering applications.

2. If the networks are constructed only on paper, they supply a visualizable schedule of operations for the numerical solution of the equations or for the improvement of the results found by the network analyzer or by other methods.

3. The networks may serve to check the accuracy and self-consistency of results arrived at by other methods, approximate or exact.

4. In many problems where the fields have boundaries of unusual shape, or where both fields and circuits are present and mutually are influencing each other, it is next to impossible to formulate the problem mathematically. In such cases the electrical model representation offers a practical means for formulating and solving the problem.



$$\text{Div } a \text{ grad } \phi = b_2 \frac{\partial \phi}{\partial t} + b_3 \phi + b_4$$

(Div $\rho . V = Q$ Curl $V = 0$)

Figure 1. Scalar-potential equation

(*a*). *Two dimensional*
(*b*). *Three dimensional*

If the networks are logically constructed and not by "brute force" they also supply the practical engineer with visualizable physical structures to play with and think with in place of abstract mathematical formulas. Although it may appear too far stretched to recall how the concept of the equivalent circuit of an induction motor promoted the understanding of its performance—and thereby its design—by the engineer, nevertheless, such a physical picture for example as a 2-dimensional transmission-line describing the formation of a *TE* or *TM* mode can not but help to contribute in the long run to the understanding and visualization of electromagnetic wave-phenomena in structures of various shapes and compositions.

The currents and voltages in all networks to be shown represent line-, surface-, and volume-integrals of field quantities measured along an infinitesimal cube. Also, the networks are valid (unless otherwise stated) for all orthogonal curvilinear co-ordinate axes. For the three most common reference frames the variables u^α and the metrical coefficients h appearing in most figures are given in Table I. Their values in other orthogonal frames (such as elliptic and spheroidal) may be found in advanced texts.

Table I. Values of u^α and h

	u^1	u^2	u^3	h_1	h_2	h_3
Cartesian	x	y	z	1	1	1
Cylindrical	r	θ	z	1	r	1
Spherical	r	θ	φ	1	r	$r \sin \theta$

THE SCALAR-POTENTIAL NETWORK

Until the last few years the only known electrical model of a partial differential equation consisted of a set of resistances arranged in squares or cubes, sometimes with capacitors connected from each junction to ground[1] or with currents impressed at the junctions. The model represented various cases of Laplace's and Poisson's equations.

All such networks may be assumed to represent special cases of the scalar-potential equation

$$\text{div } a \text{ grad } \phi = b_1 \frac{\partial \phi}{\partial t} + b_2 \phi + b_3 \tag{1}$$

These more general networks are shown in Figure 1.

Full text of a conference paper presented during the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948.

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This article presents a summary of equivalent circuits (electrical models) that have been developed and published by the author during the last few years to represent some of the basic linear partial differential equations of mathematical physics. The networks are valid for all orthogonal curvilinear co-ordinate systems and represent transient, sinusoidal, or static field phenomena. Besides the well-known Laplace and Poisson equations, the various models represent the general scalar-potential and vector-potential equations, the compressible fluid flow equations in the hodograph plane, the electromagnetic field equations of Maxwell, the wave equations of Schrödinger, and the basic equations of the theory of elasticity. The networks are capable of solving by means of an analyzer or by numerical methods initial-value, boundary-value, and characteristic-value problems.

The resistances arranged in squares or cubes represent the coefficients $\boldsymbol{a}$ (all boldface letters stand for matrices), while the right-hand coefficients b are capacitors or resistors connected from junction to ground. The b_3 coefficients are represented by currents impressed at the junctions. All coefficients $\boldsymbol{a}$ and b are functions of the space variables u^α. The potential difference between junction and ground gives the value of ϕ at that point of the field.

It is possible to give another physical interpretation to the model. Assuming the flow of a nonviscous fluid as an example, let its velocity vector be $v=\text{grad}\ \phi$ and its density be ρ. Then within the network the two laws of Kirchhoff's ($\Sigma i=0$ and $\Sigma e=0$) represent the following equations:[2]

$$\text{div}\ \rho v=Q \qquad \text{curl}\ v=0 \tag{2}$$

respectively, where Q is the right-hand side of equation 1. These are the equations of an "irrotational" flow in which sources Q exist but no vortices.

Such resistance networks have been used in the past to represent incompressible fluid flow, electrostatic and magnetic flux distributions, conduction of heat, torsion of shafts, diffusion of neutrons, and so on. There is hardly a branch of physics in which the scalar-potential equation finds no application.

It may be mentioned that a more general equation may involve the time as a second order derivative also

$$\text{div}\ \boldsymbol{a}\ \text{grad}\ \phi=b_1\frac{\partial^2\phi}{\partial t^2}+b_2\frac{\partial\phi}{\partial t}+b_3\phi+b_4 \tag{3}$$

The corresponding equivalent circuits are shown in reference 2, Figures 12*b* and 5*b*.

THE VECTOR-POTENTIAL NETWORKS

A more general type of flow of a nonviscous fluid is the "solenoidal" flow, in which vortices exist but no sources. It is described by the vector-potential equation

$$\text{curl}\ \boldsymbol{c}\ \text{curl}\ \psi=\boldsymbol{d}_1\frac{\partial\psi}{\partial t}+\boldsymbol{d}_2\psi+\boldsymbol{d}_3 \tag{4}$$

in which the dependent variable ψ is a vector and not a scalar. If $\rho v=\text{curl}\ \psi$, then Kirchhoff's two laws in the network correspond to the equations

$$\text{div}\ \rho v=0 \qquad \text{curl}\ v=\Gamma \tag{5}$$

respectively, where Γ is the right-hand side of equation 4.

Assuming a 2-dimensional solenoidal field (two degrees of freedom) in orthogonal curvilinear co-ordinates, there are now two different representations of it instead of one. In one of these ψ flows in the plane of the network, hence it has two components, in the other ψ flows perpendicularly to the plane of the network and has only one component.

The equivalent circuits (Figure 2*a*) contain resistors arranged in squares as in the scalar-potential network. But the previous junction-to-ground units instead are now arranged in circles at the corners of the squares. Also, two opposite quadrants of the circles are coupled by ideal transformers.

If the roles of voltages and currents are interchanged, a "dual" equivalent circuit may be developed (Figure 2*b*) that is similar to the scalar-potential network of Figure 1*a* and contains no ideal transformers.

Both of these basic networks are used simultaneously when the 3-dimensional field splits up into two 2-dimensional fields (ψ flowing in the plane of the network and perpendicular to it) that however are not independent of each other. In that case one of the fields must be represented by the circular network, the other by the square one. The two networks are interconnected in the appropriate manner.

The equivalent network of a 3-dimensional field is a straightforward generalization of the circular network to a spherical network (Figure 3) containing ideal transformers between opposite quadrants. Unlike the case of two dimensions, the "dual" of Figure 3 is a network of similar shape (shown in reference 2, Figure 8*c*) still containing ideal transformers.

It may be mentioned that a more general vector-potential equation may involve time as a second order derivative

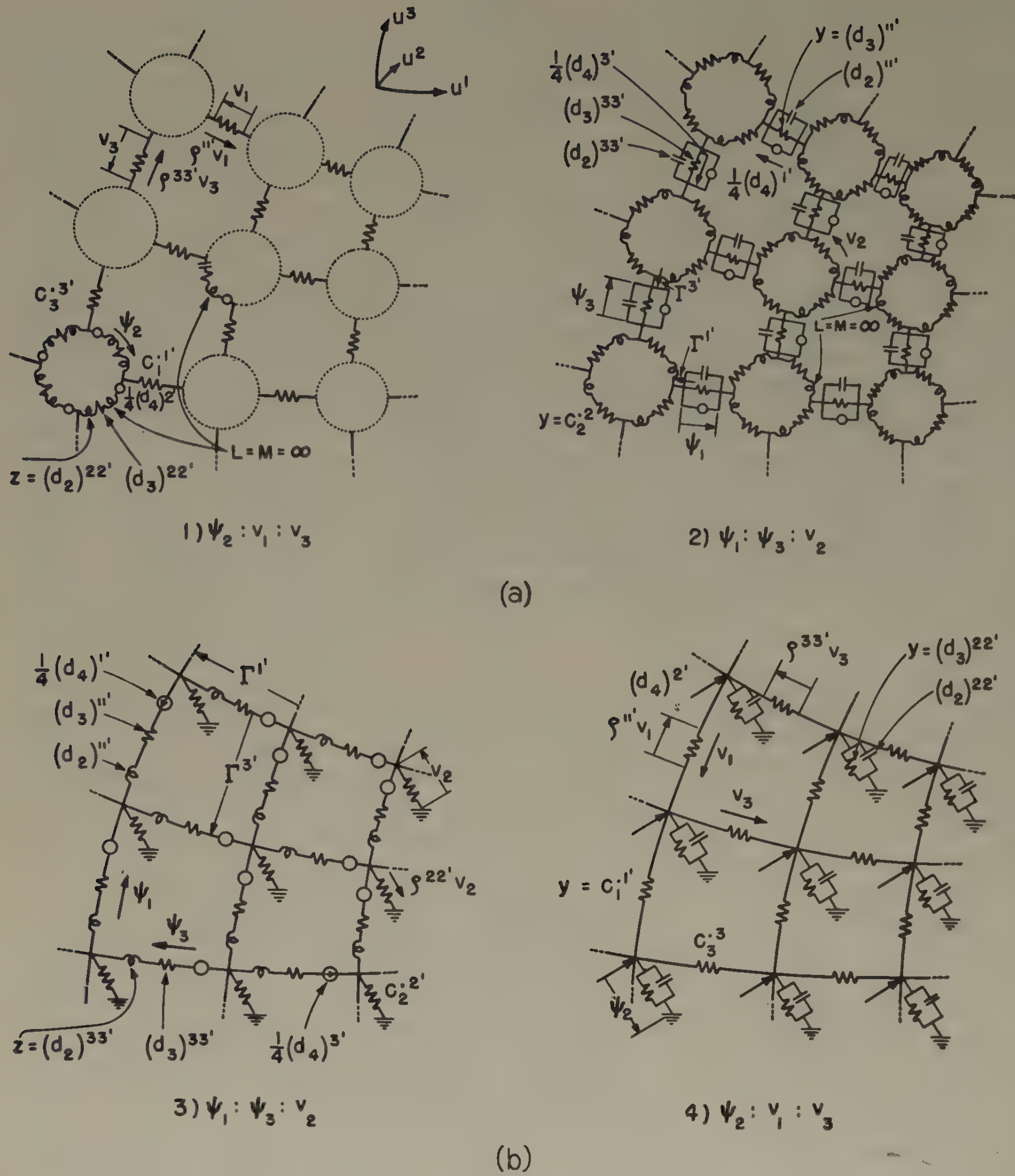
$$\text{curl}\ \boldsymbol{c}\ \text{curl}\ \psi=\boldsymbol{d}_1\frac{\partial^2\psi}{\partial t^2}+\boldsymbol{d}_2\frac{\partial\psi}{\partial t}+\boldsymbol{d}_3\psi+\boldsymbol{d}_4 \tag{6}$$

The corresponding equivalent circuits are shown in reference 2, Figures 14 and 7.

MAGNETIC FLUX DISTRIBUTION IN CURRENT-CARRYING REGIONS

An example of the dual vector-potential network is the magnetic field produced by a current flowing perpendicular to the plane of the network in conductors of arbitrary cross sections, Figure 4*a*. (The scalar-potential network, in which the flux lines are represented by currents, can be used only if the current in question flows at the boundaries or at isolated points.) In the network of Figure 4*b* the given current distribution i is represented by known currents impressed at the junctions and the resulting flux densities B by differences of potentials appearing between the junctions.

Where iron forms the boundaries, the network currents H are zero and where a flux line forms the boundary the voltages are zero. (See also reference 2, Figure 19.)



$$\text{Curl } C \text{ Curl } \psi = d_2 \cdot \frac{\partial \psi}{\partial t} + d_3 \cdot \psi + d_4$$

$$(\text{Div } \rho \cdot V = 0 \qquad \text{Curl } V = \Gamma)$$

Figure 2. Vector-potential equation (two dimensional)

(*a*). *The basic network*
(*b*). *Its dual*

COMPRESSIBLE FLUID FLOW

Another example of the vector-potential network is the flow of a compressible fluid, when the flow is expressed in the hypothetical hodograph plane, Figure 5. On the analyzer the necessary positive and negative resistances are replaced by the more practical inductors and capacitors, respectively. It should be noted that the change from inductors to capacitors occurs at the boundary between the subsonic and supersonic regions. (For experimental results see reference 3.)

An interesting phenomenon is the appearance of multiply connected regions (Riemann sheets) joined together at singular points, Figure 6. (Reference 2, Figure 17.) At this region each point of space has two or more vector potentials assigned to it. On the equivalent circuit of such a region there are no traces of a branch cut, in conformity with the fact that its particular location has no physical significance.

THE FIELD EQUATIONS OF MAXWELL

A more general case is the field equations of Maxwell which include both the scalar and vector potential equations as special cases. In general the network satisfies the following wave equation:

$$\text{grad } \mu^{-1} \text{ div}\psi - \text{curl } \mu^{-1} \text{ curl } \psi = \epsilon \frac{\partial^2 \psi}{\partial t^2} + \sigma \frac{\partial \psi}{\partial t} \tag{7}$$

Now not only the electrical network quantities, namely, *e* and *i*, enter into the physical representation, but also the underlying magnetic and dielectric networks. In particular (see reference 5, page 291).

1. The curl equations are represented by Kirchhoff's two laws for the electrical meshes and junction pairs, respectively,

$$\text{curl } \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = 0$$

$$\text{curl } \boldsymbol{H} - \frac{\partial \boldsymbol{D}}{\partial t} - \boldsymbol{I} = 0 \tag{8}$$

2. The divergence equations are represented by Kirchhoff's two laws for the magnetic meshes and dielectric junction pairs, respectively,

$$\text{Div } \boldsymbol{B} = 0 \quad \text{Div } \boldsymbol{D} = \rho \tag{9}$$

3. The constitutive equations represent Ohm's law for all three types of networks

$$B = \mu H \quad \boldsymbol{D} = \epsilon \boldsymbol{E} \quad \boldsymbol{I} = \sigma \boldsymbol{E} \tag{10}$$

The nonlinear expression ρv for the motion of free charges is not included in the network.

THE DUAL NETWORKS

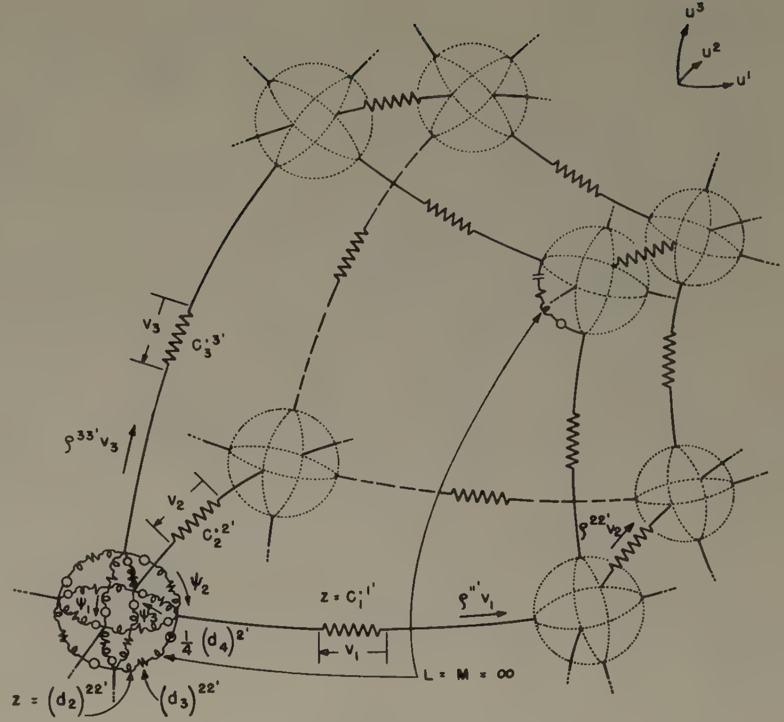
In two dimensions the basic type of network, Figure 7*a*, contains capacitors arranged in squares and inductors arranged in circles at the corners of the squares. Again two opposite quadrants are coupled by ideal transformers.

The "dual" network is of square shape (Figure 7*b*) and assumes the form of a 2-dimensional transmission line with nonuniform *R*, *L*, *C* constants.

Each of these networks may represent either a *TM* mode ($E_1E_3H_2$) or a *TE* mode ($H_1H_3E_2$) in any orthogonal curvilinear co-ordinate system.

The field distributions to be represented by equivalent circuits may be either transient or sinusoidal functions of time and the wave may travel either in free space or in

Figure 3. Vector-potential equation (three dimensional)



$$\text{Curl } C \text{ curl } \psi = d_2 \cdot \frac{\partial \psi}{\partial t} + d_3 \cdot \psi + d_4$$

$$(\text{Div } \rho . V. = 0 \qquad \text{Curl } V = \Gamma)$$

any dielectric and conducting media. Conducting boundaries are represented by open- or short-circuits, while free space, at a distance from conductors, is terminated by the characteristic resistance of free space, $R_0 = 377$ ohms.

The networks determine the impedances, natural frequencies, and modes of oscillation of cavity resonators of arbitrary shape (Figures 9 and 10). For further experiments see reference 6. The cavities may contain "lossy" material, for instance, resistances may imitate the arrangement of food in a container to be heated by microwaves. Such an axially symmetric cavity with a disk radiator is shown in Figure 11. Assuming spherical symmetry the resultant electrical models may be used for the study of radiation from antennas.

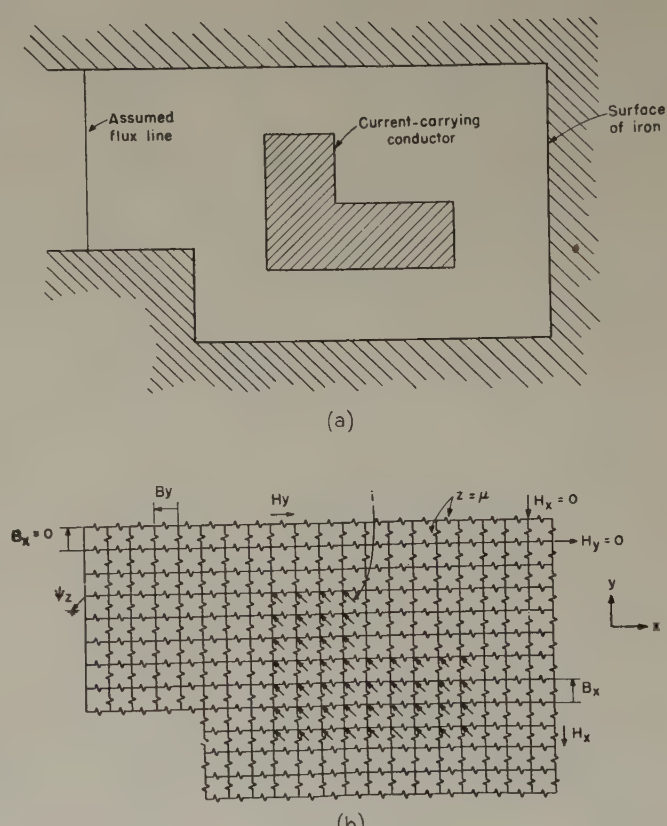
MORE GENERAL 2-DIMENSIONAL NETWORKS

A more general 2-dimensional field may contain all six field-components $H_1 H_2\ H_3$ and $E_1 E_2 E_3$, each being a function of two spatial variables u^1 and u^3. (Along the third direction u^2 the variation of each of the six quantities is assumed to be known.) Such a general 2-dimensional field always can be considered of consisting of two interdependent simpler 2-dimensional fields (one being a *TE*, the other a *TM* wave). Then one of the simpler fields may be represented by the square transmission line-like network, while the other by the circular network containing ideal transformers. The interconnection of the two networks is accomplished by an appropriate circuit. An example is the field of a wave guide of arbitrary cross section but uniform along one direction. Another example is the field around a helical coil. In general an electric circuit of arbitrary shape and the field surrounding it are to be represented by such combined networks.

THE 3-DIMENSIONAL NETWORK

The general 3-dimensional field is represented (in any orthogonal curvilinear frame) by a straightforward generalization of the circular network into a spherical network (Figure 8) containing ideal transformers between opposite quadrants. Unlike the case of simple 2-dimensional networks, the "dual" of the 3-dimensional network is one of similar shape (reference 5, Figure 3) still containing ideal transformers.

Hence it can not be said that the field equations of Maxwell are represented by a 2- or 3-dimensional transmission line. It is only fortuitous that in two dimensions one of the networks (representing a simple *TE* or *TM* mode) happens to assume the form of a 2-dimensional transmission line with nonuniform constants. The general 2-dimensional field is represented by a far more complex 2-dimensional network. In three dimensions the model has no similarity at all to a transmission line.



$$\text{Curl } \mu^{-1} \text{Curl } \psi = I$$

$$(\text{Div. } \mathbf{B} = 0 \qquad \text{curl } \mathbf{H} = I)$$

Figure 4. Magnetic flux distribution in current-carrying regions

(*a*). *An electromagnetic problem*

(*b*). *Its equivalent circuit*

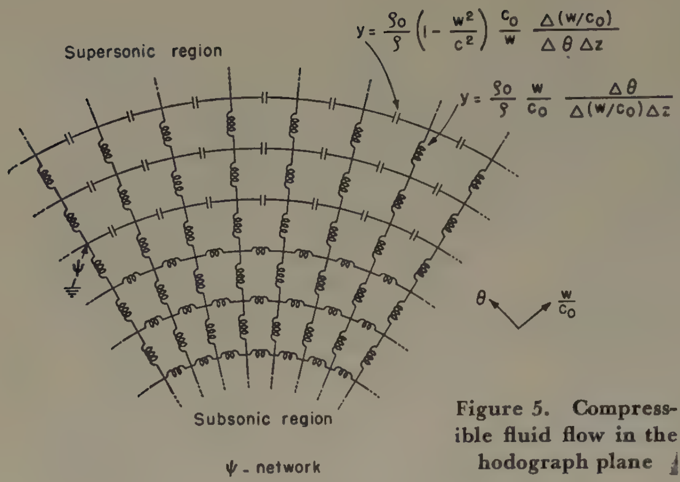
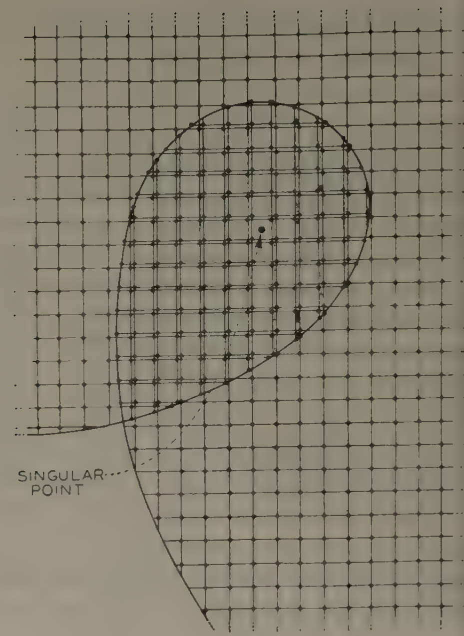


Figure 5. Compressible fluid flow in the hodograph plane

Figure 6. Equivalent circuit representation of multiply connected regions



PHYSICAL INTERPRETATION

Attention is called to the fact that every single physical quantity that can be measured on the network represents the line, surface, or volume integrals of some one of the field quantities. In particular, considering first the currents in the network

1. The currents in the inductors represent $\boldsymbol{H}$.
2. The currents in the capacitors represent the "displacement currents" $p\boldsymbol{D}$.
3. The currents in the resistors represent "conduction currents" $\boldsymbol{I}$.

Considering next the differences of potentials in the network

4. The voltages across the capacitors and resistors represent $\boldsymbol{E}$.
5. The voltages across the inductors represent the "magnetic displacement currents" $p\boldsymbol{B}$.

Considering some of the network's other physical quantities

6. The magnetic flux lines represent $\boldsymbol{B}$.
7. The electrostatic flux lines represent $\boldsymbol{D}$.
8. The charges on the capacitors represent ρ.

Considering the various constants of the network elements

9. The inductances represent the permeability μ of a unit cube of material in a direction indicated by the indexes.
10. The capacitances represent the specific inductive capacity ϵ of a unit cube of material.
11. The resistances represent the conductivity σ of a unit cube of material.

Just as the scalar-potential network of Figure 1, the equivalent circuit of the electromagnetic field may be interpreted physically also from another point of view. The network may assume to represent the distribution of the scalar potential ψ, the vector potential $\boldsymbol{A}$, the Hertzian potential π, and so forth, and their duals.

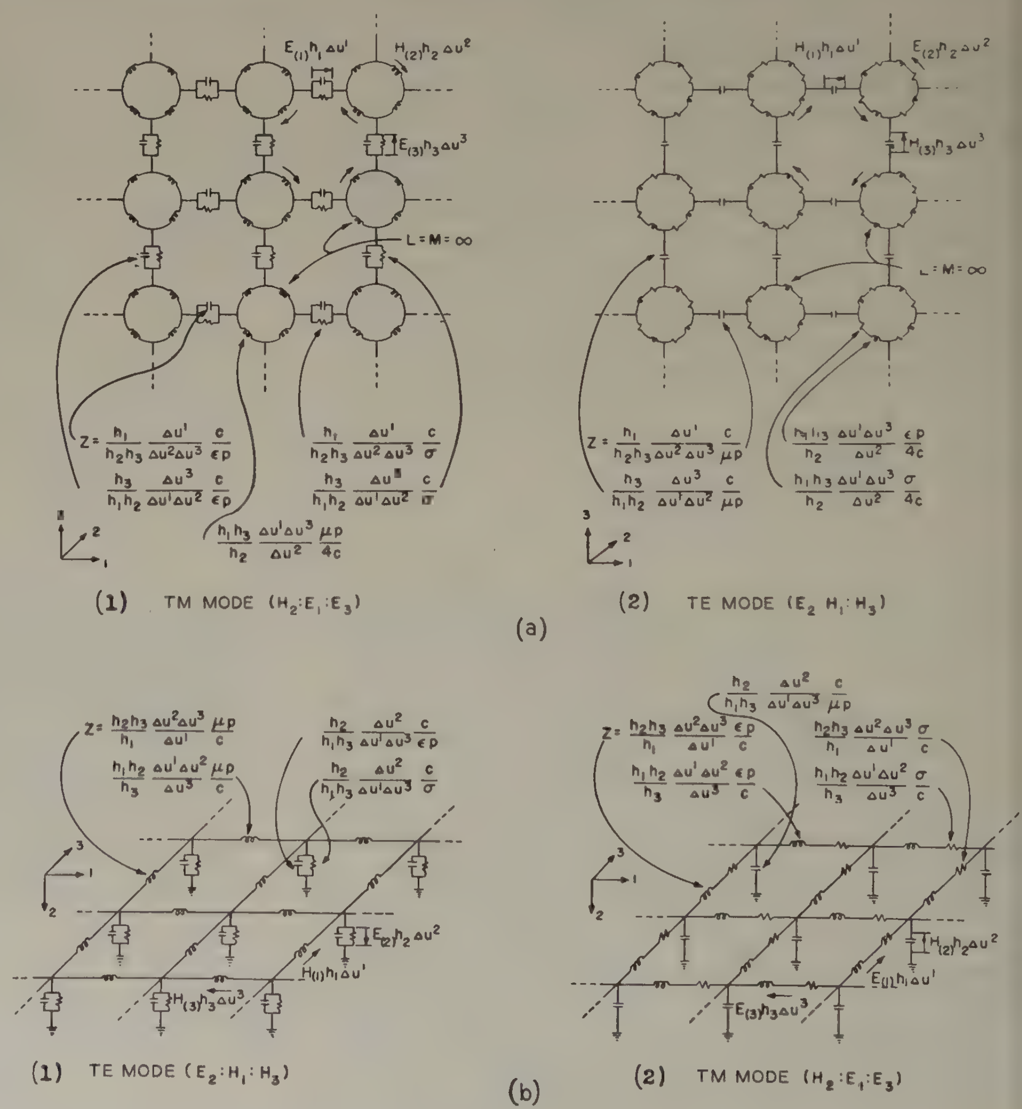


Figure 7. Field equations of Maxwell—two dimensional
(a). The basic network (b). Its dual

THE HIGH-FREQUENCY ANALYZER AT STANFORD

The available a-c analyzers constructed for the study of power transmission systems contain too few units to represent a 2-dimensional field with a reasonable accuracy. Nevertheless the results arrived at with their help showed conclusively the correctness and practicability of the circuits developed.

The next step in the practical utilization of the electrical models was undertaken by Professor Karl Spangenberg of Stanford University. Under a Navy contract he constructed an axially symmetric transmission-line-like network containing about 1,300 inductors and 650 capacitors of fixed magnitude. The board is excited by a generator whose frequency varies within the range of several hundred kilocycles (Figure 12).

The board already has been used for over a year to find equivalent impedances, resonant frequencies, reactance, and propagation characteristics of cavities. The effect of obstacles, corners, and dielectrics in lines, resonators, and wave guides also have been investigated. The board gave consistently results with an accuracy better than two per cent.

An example for the field distribution of a short-circuited coaxial line is given in Figure 13 showing theoretical and test points. Detailed description of this first high-frequency analyzer and of the work done on it was given in "A Network Analyzer for the Study of Electromagnetic Fields," presented at the 1948 winter convention of the Institute of Radio Engineers by K. Spangenberg, G. Walters, and F. W. Scott.

THE WAVE EQUATION OF SCHRÖDINGER

An equation analogous to but not quite identical with the scalar potential equation 1 is the wave equation of

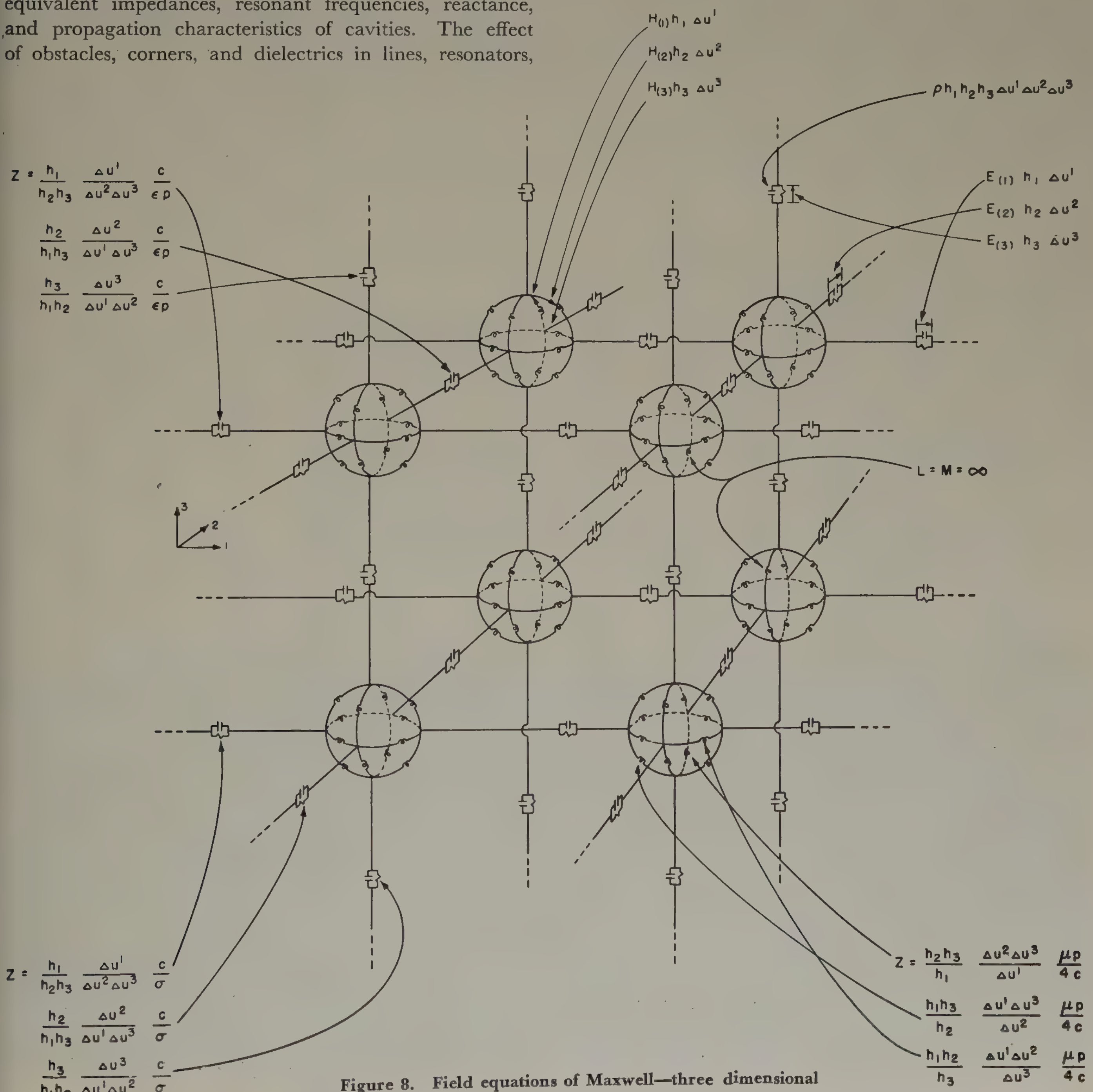


Figure 8. Field equations of Maxwell—three dimensional

Schrödinger (not containing the time)

$$-\frac{h^2}{2m}\text{Div } a \text{ grad } \phi+(V-E)\phi=0 \tag{11}$$

that describes the waves associated with atomic and nuclear particles. The equation satisfies only Kirchhoff's second law (the summation of currents is zero at each junction) and no equation satisfies the first law. (See reference 9).

Here the problem is to find, for a given spatial function of the potential energy V those discrete values of the total energy E (*eigen* values) at which ϕ (the *eigen* function) does have an existence. The 1-dimensional model is shown in Figure 14 and the 3-dimensional in Figure 15. By varying the values of all the capacitors simultaneously the current flowing in a generator inserted across one of the capacitors is observed. When that current is zero, the capacitor values give the total energy E and the differences of potential between the various junctions and the ground give the wave function ϕ. The power in a set of similar admittances represents the statistical mean of the corresponding energy operator.

Figure 16 shows the shape of the potential barrier of a radioactive nucleus and its energy levels, as found on the a-c network analyzer. The wave functions belonging to two discrete energy levels are shown in Figure 17 and those belonging to two virtual energy bands (the two extreme levels in each band) are shown in Figure 18. Thirty-two divisions were assumed on the analyzer. For further tests see reference 10.

THE EQUATIONS OF ELASTICITY

More complicated sets of equations than those describing scalar and vector potentials are the basic equations of elastic bodies. Here the equivalent network must satisfy simultaneously three sets of equations. (See reference 11.)

1. The "equations of equilibrium" representing three relations between the displacements s.

$$\text{grad } (\lambda+2\mu) \text{ div } s\text{-curl } \mu \text{ curl } s+f=\rho\frac{\partial^2 s}{\partial t^2} \tag{12}$$

(In comparing this elastic wave equation with the electromagnetic wave equation 7, note that here the coefficients in the two left-hand terms are not identical but are different. Hence the equivalent circuits have different structures.) In the network they satisfy Kirchhoff's second law $\left(\sum i=0\right)$.

2. Hooke's law, representing six relations between the stresses σ and strains e

$$\sigma=ce \tag{13}$$

In the network they satisfy Ohm's law

3. The "conditions of compatibility," representing six relations between the strains

$$K_{\alpha\beta\gamma\delta}=0 \tag{14}$$

In the network they satisfy Kirchhoff's first law $\left(\sum e=0\right)$.

In the electrical model stresses are represented by currents and strains by voltages. The elastic body may be nonhomogeneous, may rotate at a uniform angular velocity, and, for representation, may be divided into blocks of uneven lengths in different directions.

Since the network for the general co-ordinate axes appeared too complicated, it was found more practicable to develop a network for each particular reference frame separately from its equations. Two types of equivalent circuits were developed:

1. Transient networks for the study of propagation of elastic waves in nonhomogeneous bodies and for the determination of the natural frequencies of vibration. These networks contain 2- and 3-winding transformers (not ideal). Figure 19 shows a 3-dimensional network and Figure 20 an axially symmetric one.

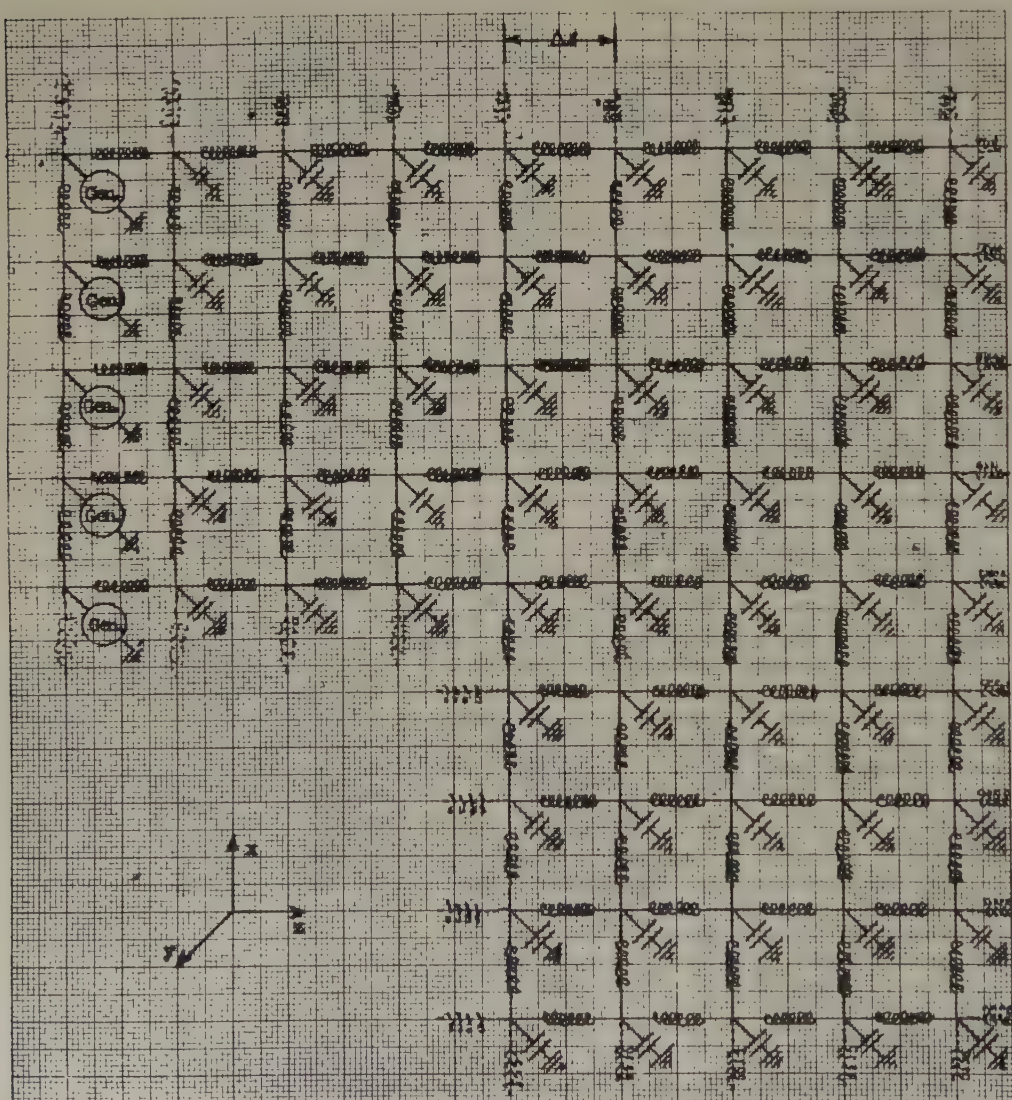


Figure 9. Network for L-shaped cavity

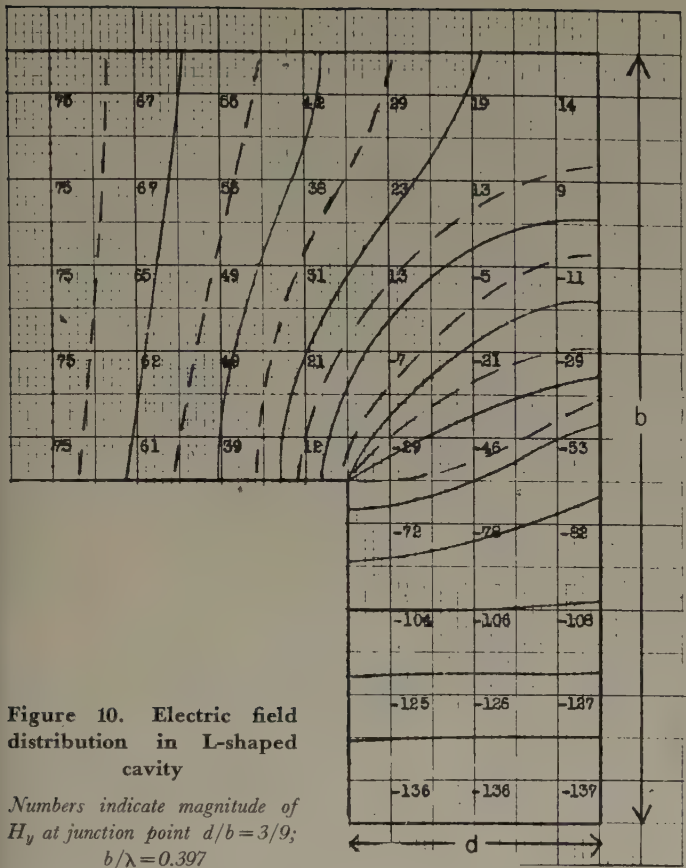


Figure 10. Electric field distribution in L-shaped cavity

Numbers indicate magnitude of H_y at junction point $d/b = 3/9$; $b/\lambda = 0.397$

2. Steady-state networks for the study of steady stressed states or of natural frequencies. These networks do not require transformers. Figure 21 shows such a network in cylindrical co-ordinates for a uniformly rotating body. The masses enter as inductors from each junction-to-ground.

One characteristic of the steady-state networks is that the impedance units around the boundaries have different values from those situated within the elastic body, since the original networks may be simplified by combining two impedances that are in parallel or in series. The simplified network of Figure 21 is shown in Figure 22. (In the scalar- and vector-potential networks there is no opportunity for such simplification.)

Figure 11. Axially symmetric container

Food is represented by resistances

Problems arising in connection with membranes and shells offer many opportunities for setting up a variety of partial differential equations and solving them by electrical models. Test and theoretical results for the displacements

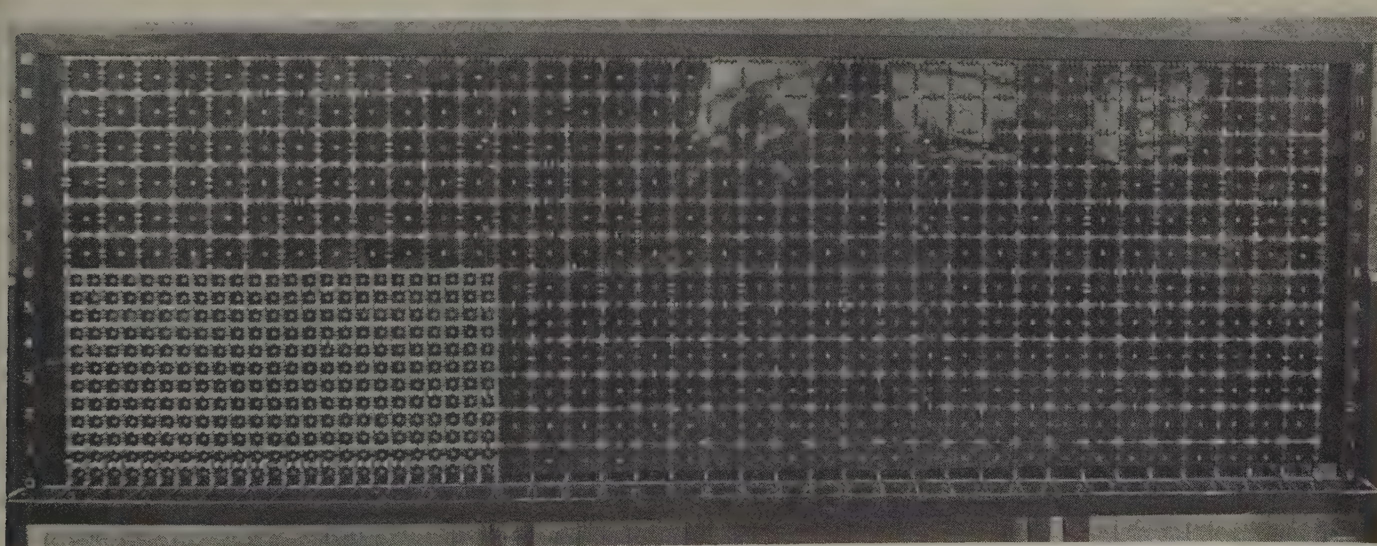


Figure 12. High-frequency analyzer of Stanford University

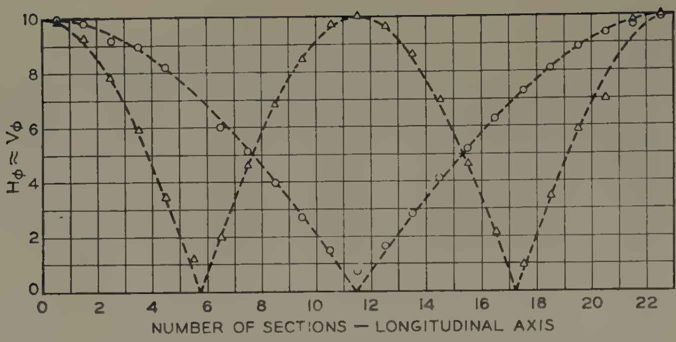


Figure 13. Theoretical and test results of a short-circuited coaxial line

Dashed lines calculated
⊙—Half wave resonator test points
△—Full wave resonator test points

Figure 14. The wave equation of Schrödinger

One-dimensional model

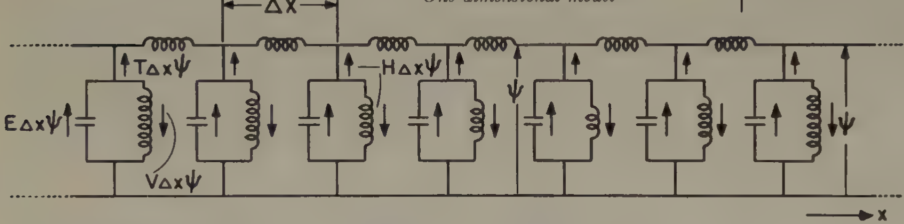


Figure 15. The wave equation of Schrödinger

Three-dimensional model

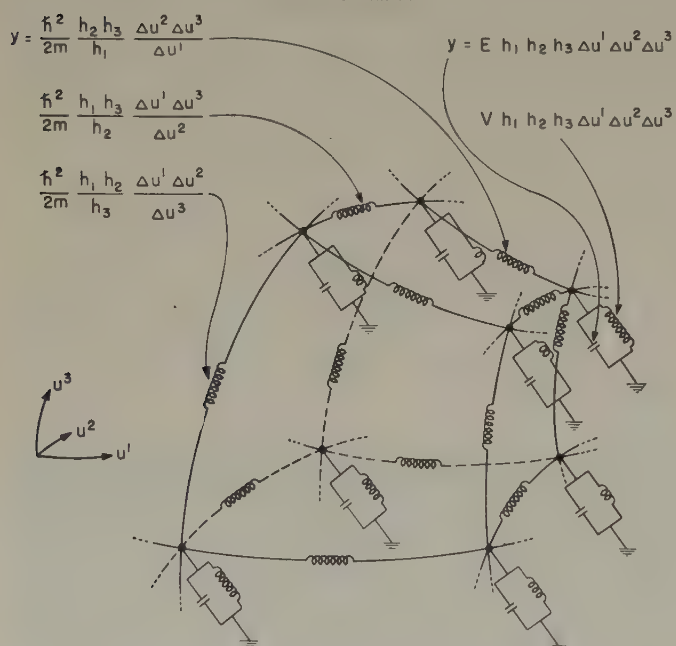
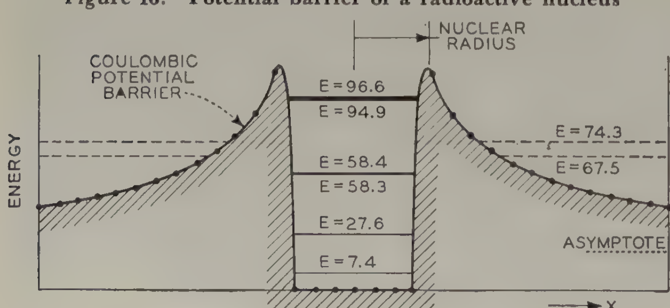


Figure 16. Potential barrier of a radioactive nucleus



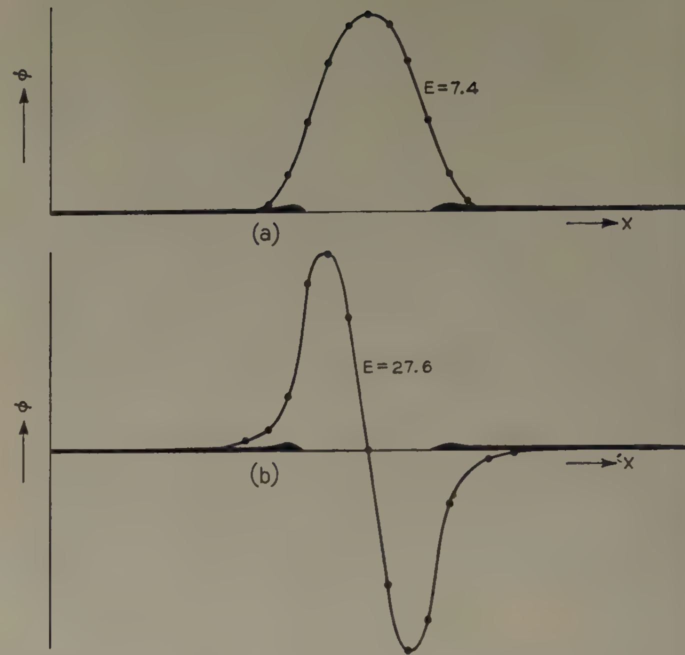
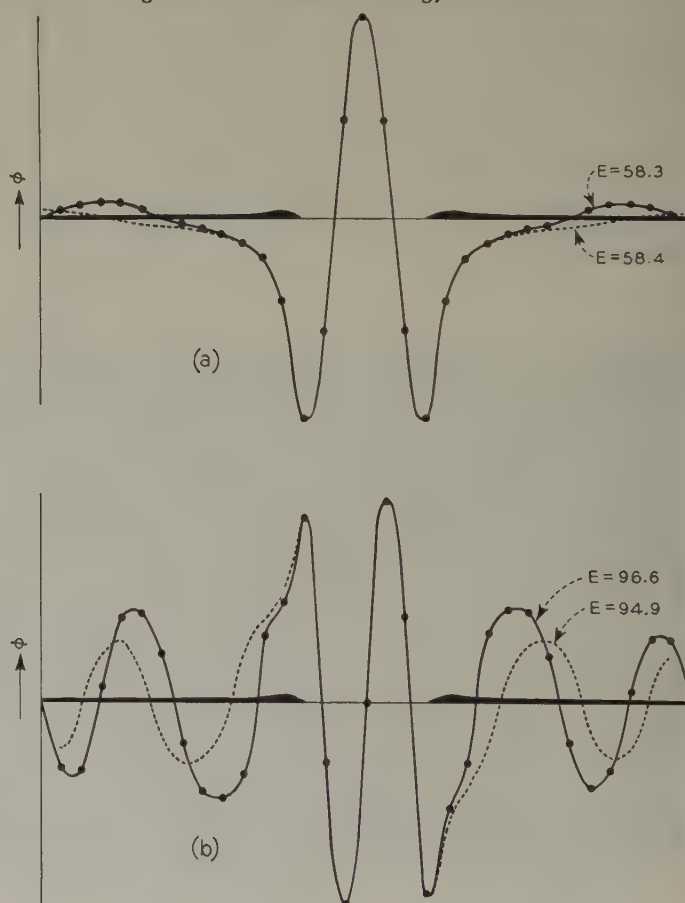


Figure 17 (above). Two discrete energy levels

Figure 18. Two virtual energy-level bands



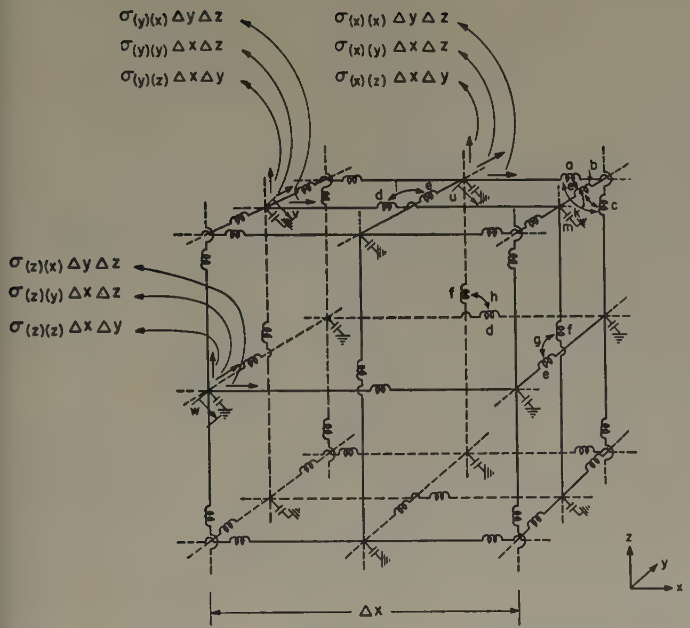


Figure 19. Transient elastic network

Three dimensional, rectangular axes

in a cylinder under internal pressure are shown in Figure 23. For further tests see reference 12.

OBSERVATIONS ABOUT MODEL TESTS

Tests on a large variety of models for various partial differential equations allow the following conclusions:

1. Good results can be expected if an impedance (or a generator) exists between every junction and the ground.

2. Good results also may be expected if impedances (or generators) exist from junction to ground around the boundaries. Such is the case for instance in compressible flow problems in the hodograph plane. (Figure 5. See also reference 3.)

3. If the network is connected to ground only at a few points (as in Figure 23) the losses of the analyzer must be supplied from additional generators by a cut and try procedure.

The resistances inherent in all inductors do distort the voltage waves as a whole but a correction factor easily may be introduced if needed.

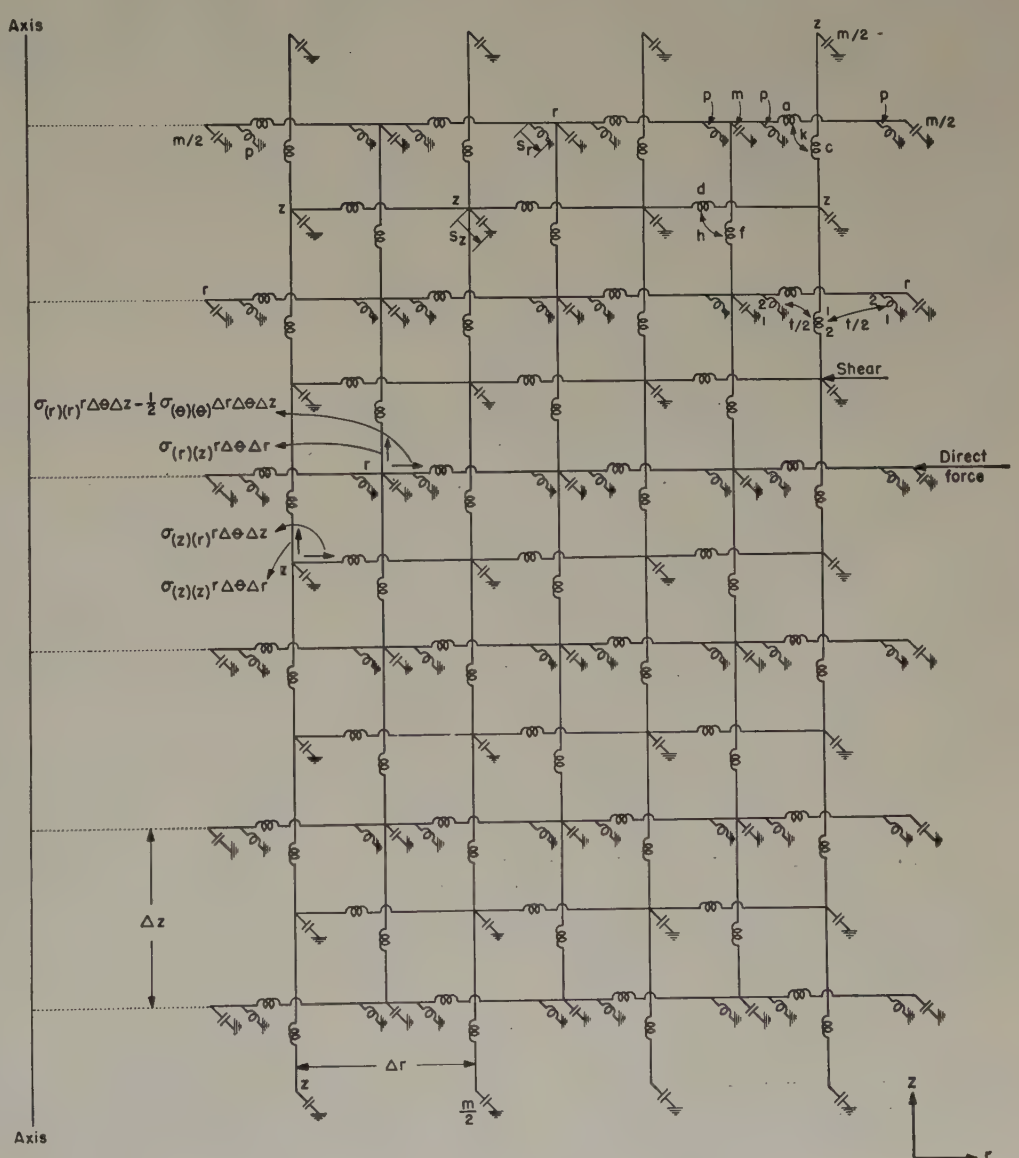


Figure 20. Transient elastic network

Axially symmetric axes

NUMERICAL SOLUTION OF NETWORKS

If the results of the analyzer are not sufficiently accurate for the purpose intended they may be further improved to any desired degree of accuracy by further numerical calculations. Also, if no analyzer is available, the networks may be used for a numerical solution by starting out with some tentative field distribution.

Time-varying ("initial value") problems may be solved in a straightforward manner by establishing networks in which time is treated as an additional spatial variable. (Reference 13, part I. In the previous networks time appeared as time.) For a transient heat-flow problem such a network and accompanying calculation is reproduced in Figure 24 in which the theoretically correct values are shown blocked. Boundary-value and characteristic-value problems may be solved by several methods. The one most advantageous for use on digital calculating machines, because of its repetitive nature, is the "method of weighted averages." (Reference 13, equations 1–6.)

Considering the improvement of the potential value at some particular junction, let the admittances leading to all neighboring junctions be y_2, y_1, ... and the one to the ground be y_0. Also, if the potentials of the neighboring

junctions are e_1, e_2, ... and the impressed current at that particular junction is I, then the improved value of the potential E is the weighted average of the neighboring potentials.

$$E=\frac{e_1y_1+e_2y_2+\ldots+I}{y_1+y_2+\ldots+y_0} \quad (15)$$

(If transformers are present, this formula must be extended.)

For the field equations of Maxwell, using the transmission-line-like network of Figure 7*b* in rectangular co-ordinates, the formula reduces to (reference 13, equations 7–14)

$$E=\frac{e_1+e_2+e_3+e_4}{k} \quad (16)$$

$$k=4+\frac{y_c}{y_L}$$

since $y_1=y_2=y_3=y_4=y_L$ and $y_0=y_c$ (a capacitor). The number k is less than 4. For Laplace's equation in rectangular co-ordinates the formula reduces to

$$E=\frac{e_1+e_2+e_3+e_4}{4} \quad (17)$$

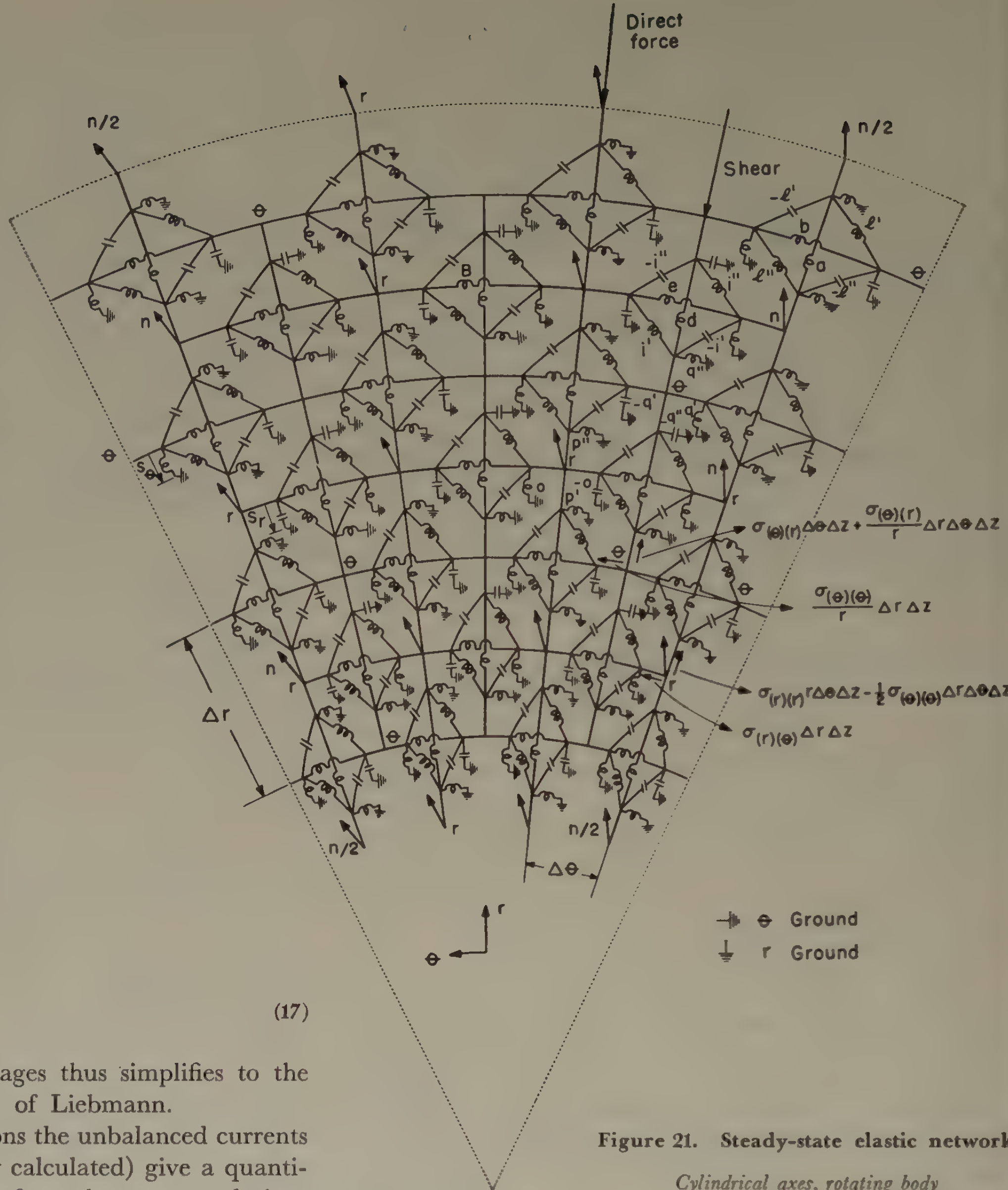


Figure 21. Steady-state elastic network

Cylindrical axes, rotating body

The method of weighted averages thus simplifies to the well-known averaging formula of Liebmann.

At any stage of the calculations the unbalanced currents existing at the junctions (easily calculated) give a quantitative measure of the deviation from the correct solution. An example is reproduced (from references 12 and 13) in Figure 25 representing a cantilever beam with the fixed end rigidly held. The shear load over the free end and a concentrated load are shown by impressed currents. The voltages at the junctions (the displacements) were calculated to five significant figures partly by the method of weighted averages and partly by a relaxation method. The unbalanced currents still existing at each junction are shown in parentheses.

Some of the largest unbalanced currents may be reduced quickly by the relaxation method of Southwell. An example of such a quick reduction is reproduced (from reference 13, page 180) for a cavity resonator in Figure 26, where the largest unbalanced current (7.9 units) and several others have been reduced to less than 4 units (and the corresponding junction potentials corrected) by the number of steps shown.

EQUATIONS REPRESENTABLE BY A MODEL

The question arises: what partial differential equations may be represented by electric networks containing passive circuit elements? An obvious limitation is that the equations must be linear, that is, the coefficients should not be functions of the dependent variables ψ, only of the independent variables x, y, z.

A second, not so obvious, limitation is that each symbol in the equation actually should represent a physically existing entity. In other words, the equations themselves should be actual models of a physical phenomenon. The mathematical criterion of such a correspondence is that the partial differential equation to be represented by a model should be a tensor-density equation.

Now, when the engineer stumbles upon a new partial differential equation, the latter is usually a compromise of several practical considerations that ruined the physics of the problem. No matter how practical, such equations nevertheless can not be represented by an electrical or by any other model.

Luckily the basic laws of physics, developed by physicists, do correspond term by term to actual physical phenomena and consequently they are representable by models without any further change. But this remark needs further qualifications. The laws of physics, as presented in conven-

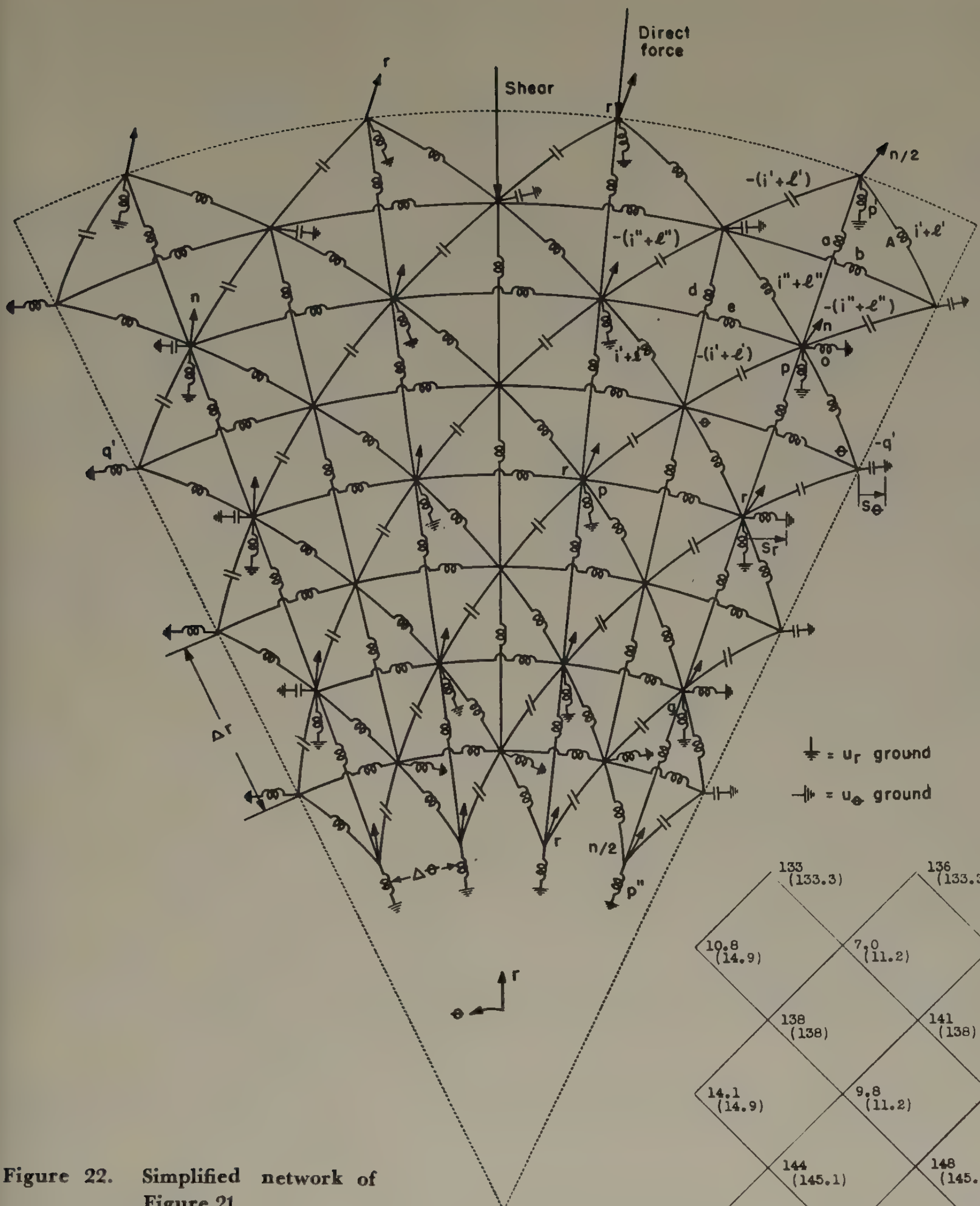


Figure 22. Simplified network of Figure 21

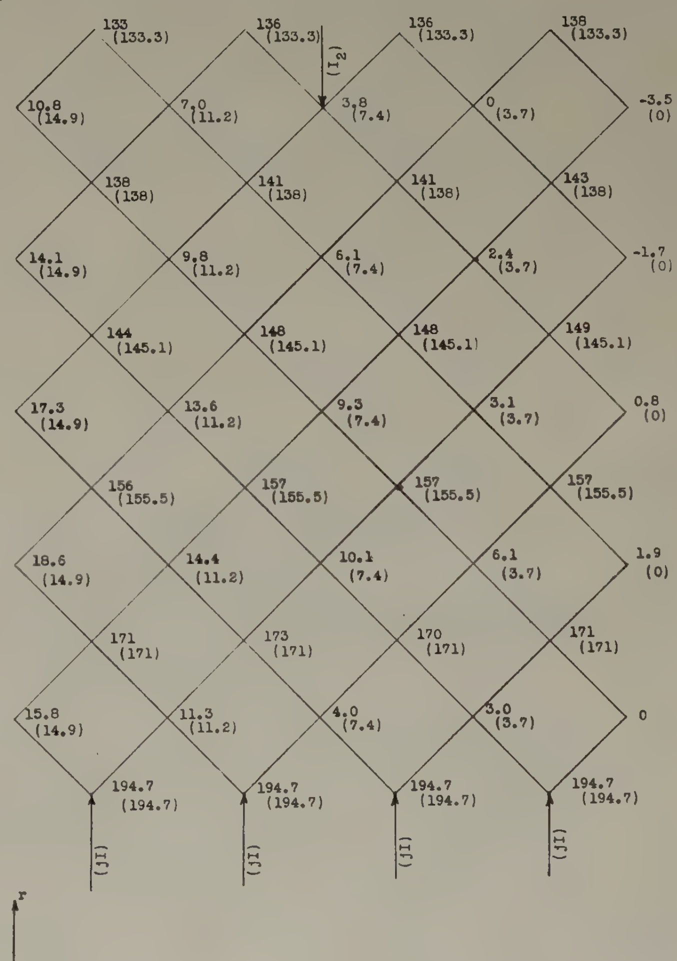


Figure 23. Cylinder under internal pressure (test and theoretical results)

tional textbooks, are in a physical, tensor-density form only when rectangular reference frames are used. That however, is not the case for curvilinear reference frames. The definitions of divergence, curl, and so forth, of conventional vector analysis represent (along curvilinear axes) not the actual physical entities, only their projections on tangent planes. As a consequence no amount of human ingenuity can ever represent such expressions by a model. For the purpose of physical visualization and for model representation such vector differential equations must be changed first to a tensor-density form, as actually has been done in the references given in deriving the electrical models shown.

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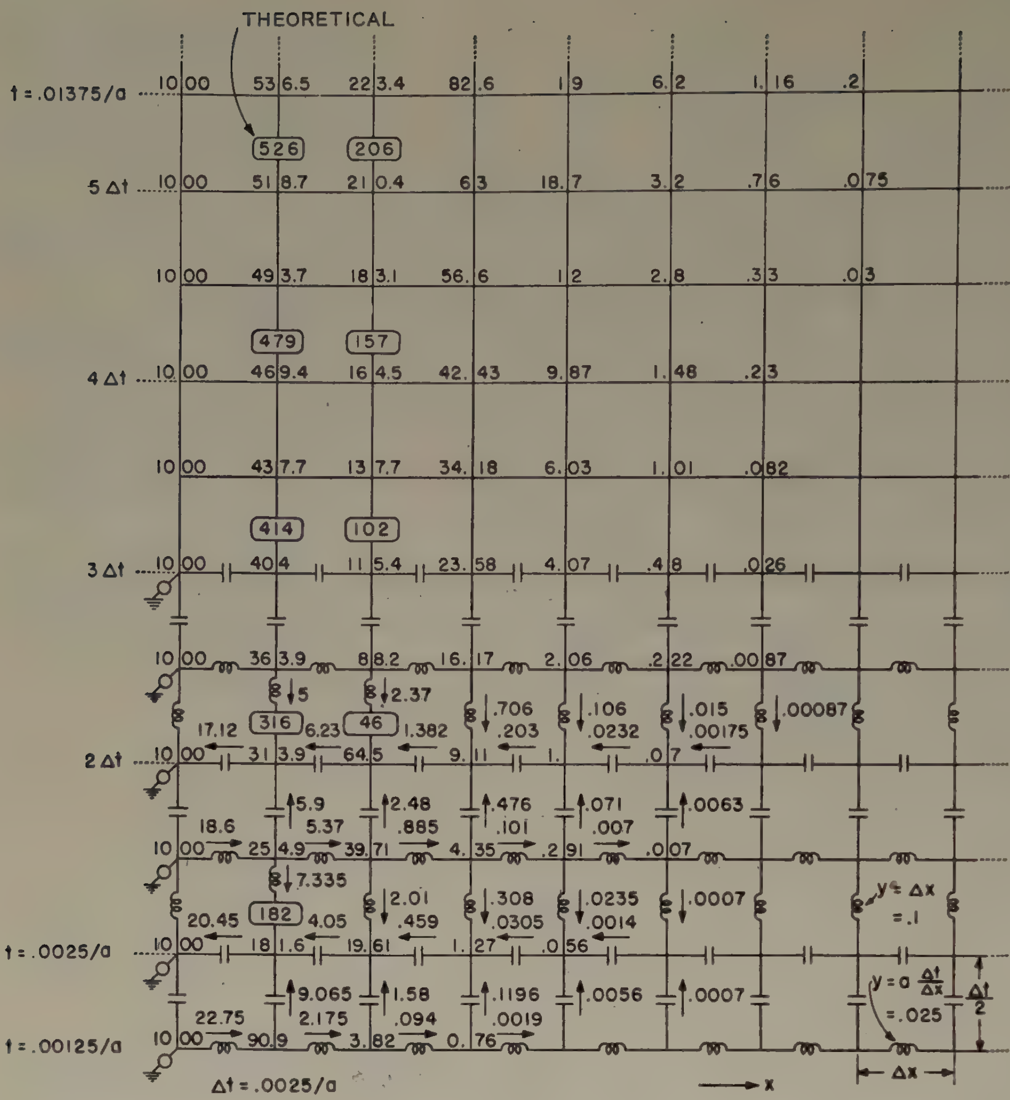

Figure 24. Transient heat flow calculations (calculated and theoretical results)

Figure 25. Cantilever beam calculations (displacements and unliquidated loads)

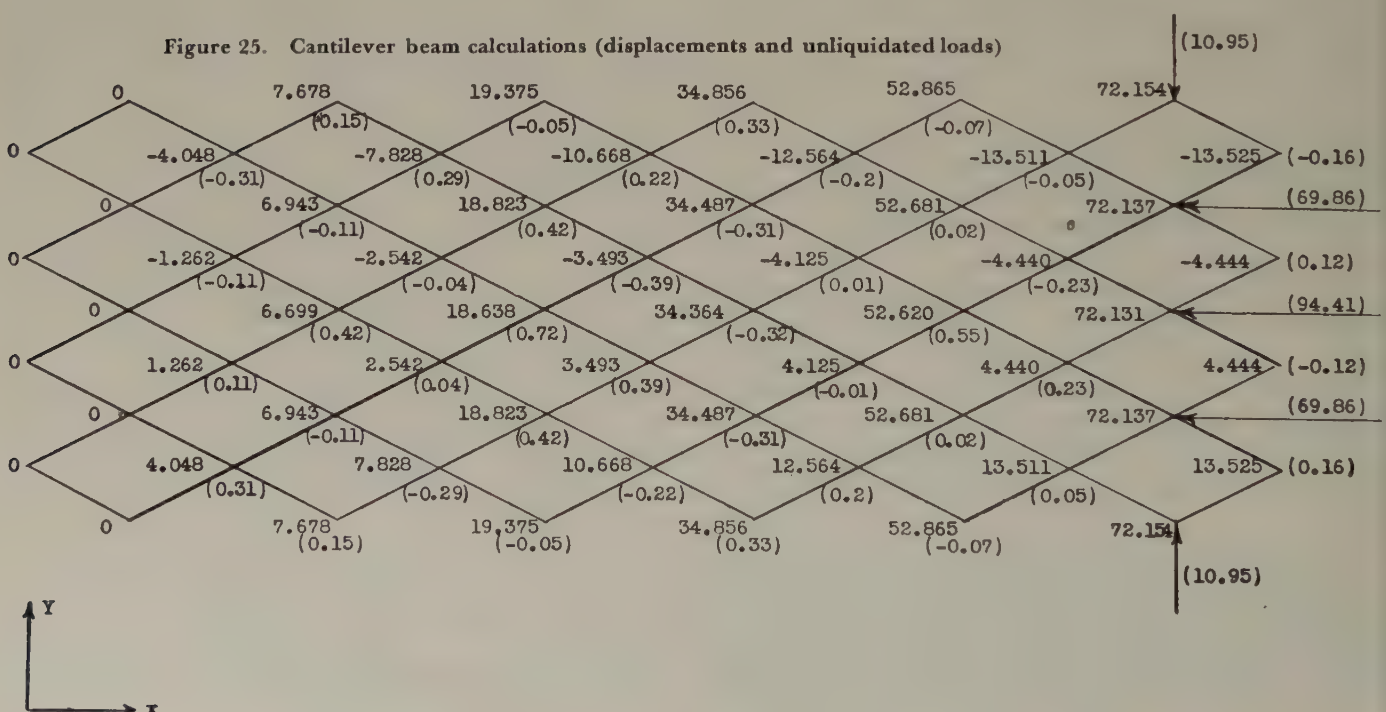

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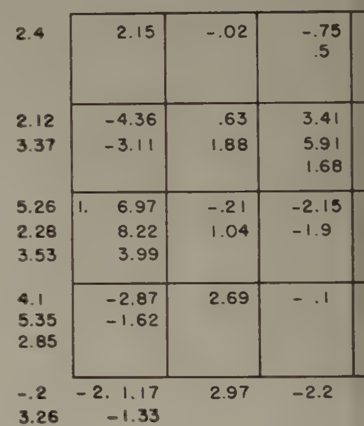
Figure 26. Reduction of unbalanced currents by the relaxation method (from eight per cent to four per cent)



Nuclear Reactors

Some Basic Considerations

F. L. FRIEDMAN

The production of energy, isotopes, and fissionable material in nuclear reactors is described both verbally and mathematically. The interrelation between raw materials, the use of convertible isotopes, and the limitations on structural materials is discussed. Though, at first glance, the equations may seem abstruse, such analysis must be studied by engineers who desire a working knowledge of nucleonics. This is the eighth in a series of articles developed by the AIEE nucleonics committee; the entire series will be published in pamphlet form upon its completion.

NUCLEAR CHAIN REACTIONS were developed during the recent war for military purposes. The most spectacular realization was the atomic bomb, which is in essence a controlled initiation of an uncontrollable nuclear chain reaction. In attempting to utilize chain reactions for most purposes, however, it is important to control, not merely the initiation, but all phases of the chain reaction. It is to the problems of well controlled reactions that this article is devoted.

Such chain reactions were investigated during the war in connection with the production of plutonium, and further work is going on under the auspices of the United States Atomic Energy Commission. This discussion will lean heavily on these joint efforts of many scientists and engineers.

Input and Output. Putting aside the thermonuclear reactions which proceed in stars, but will not run in the absence of stellar conditions, we restrict our consideration to those reactions involving the fission process. In the fission process, a fissionable nucleus is destroyed; two radioactive fragments representing most of the mass of the original nucleus are produced and some neutrons are boiled off, which in turn produce further fission in other nuclei.[1] The input of the chain reactions is the fissionable material, and the output consists of the fission fragments (usually called fission products), energy, and possibly extra neutrons. The energy output is initially in the form of kinetic energy of small particles and in that of radiations similar to X rays. (The particulate aspect of X rays and the wave aspect of material particles need not concern us here.)

Consider the output of the chain reaction a bit more closely. On the average, the heavy nuclear fragments produced in the fission of uranium have a total kinetic energy of about 167 million electron volts, (one million electron volts $= 1.6\times10^{-13}$ watt-second) and the neutrons have an average kinetic energy of about 1 million electron volts each. Energy also is released immediately in the form of radiation, and subsequently, upon the radioactive decay of the fission products. Some further radiation is produced in the nuclear processes which take place when the free neutrons are captured by other nuclei.

The total energy released per fission is approximately 200 million electron volts. (Consequently, about 3×10^{10} fissions are needed to release one watt-second of energy.)

Fission does not always take place in just the same way. Sometimes the fission products produced are one pair of radioactive atoms, sometimes another. On the average over many fissions, however, there will be fixed ratios between the numbers of fission products of various types. Much information is already available on this average distribution of fission products.[2] For this discussion, however, the important fact is that the distribution is fixed by nature. To a given large number of fissions there correspond definite numbers of fission products. Consequently, for a specified energy release in a nuclear chain reaction, a definite number and distribution of fission products is an inevitable by-product.

Any neutrons not required to keep the fission-neutron cycle going also may be considered a by-product. To some extent, such neutrons are disposable. They may be used to create radioactive isotopes to order. The number of disposable neutrons depends on the details of the reactor design and so also does the range in the free choice of and efficiency of conversion into radioactive atoms.

As neutron capture does result automatically in changing the isotope which captures, it should be possible to make the total number of isotopic transmutations equal to the number of extra neutrons.

To be fair in considering the transmuted isotopes as part of the output of a chain reaction, those isotopes which are to be transmuted should be added to the input. The determination of the radioactive isotopes produced by the extra neutrons is put into effect by incorporating in the design of the reactor the appropriate isotopes for transmutation and eliminating those on which neutrons should not be wasted.

Convertible Isotopes. Among the possible isotopes which may be incorporated in the reactor design there is a particularly important group which shall be called the convertible isotopes. They are defined by the fact that upon capturing a neutron they become fissionable.* The isotopes ${}_{92}U^{238}$ and ${}_{90}Th^{232}$ are convertible. Upon neutron capture ${}_{92}U^{238}$ is changed to ${}_{92}U^{239}$, which soon becomes the isotope of plutonium ${}_{94}Pu^{239}$ through radioactive decay.

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* Multiply convertible isotopes might be defined through successive neutron captures. Singly convertible isotopes will suffice here.

Similarly $_{90}Th^{232}$ becomes $_{90}U^{233}$. Both these isotopes are fissionable. They therefore may serve as nuclear fuels, offsetting the input requirements of the chain reaction, or rather shifting part of the input requirement from fissionable isotope to convertible isotope.

The possibility of using convertible isotopes may have a significant effect on the future of nuclear chain reactors. A glance at the problem of raw materials will give one of the reasons. The natural abundance of the convertible isotope $_{92}U^{238}$ is 140 times that of the fissionable isotope $_{92}U^{235}$, and the abundance and availability of thorium is considerably (about ten times) greater than that of uranium.[3,4] It follows that the reserves of atomic energy which can be tapped increase with the ability to use convertible isotopes, and a premium is placed on chain reactors so designed as to provide many extra neutrons.*

Another reason for the importance of convertible isotopes stems from the fact that the nuclear fuel produced is an isotope of a different element: plutonium is made from uranium; uranium (233) from thorium. The nuclear fuel therefore can be separated from the convertible isotope bed by chemical means. Essentially pure fissionable isotope is thus available.

Nearly pure isotopes also can be supplied by physical separation. $_{92}U^{235}$ can be separated from $_{92}U^{238}$, but the physical separation of neighboring heavy isotopes is usually far harder than the chemical—provided only that a chemical distinction between the isotopes exists.

The comparative ease of chemical separation was the reason for undertaking plutonium production during the war. Pure fissionable material was needed then for a bomb. Now it is possible that the pure fissionable material will be used to change the types of chain reactors built in the future.[7] The size of the reactor and the composition of the input no longer are limited by the necessity of using natural uranium.

Other Isotopes. In the long run the ability to produce isotopes to order well may have an effect as important as that of releasing nuclear energy as a source of more or less conventional power. Radioactive tracers are a powerful analytic tool for chemical and biochemical research. They probably can be used as control agents in the regulation of industrial processes. By accelerating technological advance, isotopes may contribute more to the world's income than will the added heat or electricity.

For the time being, however, the demand for isotopes easily can be met without a large release of nuclear energy. Nor is this situation likely to be of short duration. A watt corresponds to 3×10^{10} fissions per second, approximately the same number of fissions as the number of radioactive disintegrations given by a gram of radium. From the average fission several radioactive disintegrations follow, and even for isotopes produced by a thousandth of a spare neutron per fission a kilowatt keeps in existence the equivalent of a gram of radium in these isotopes alone. No doubt some useful isotopes may be in short supply, but in a very real sense the potential supply of radioactivity far outruns our knowledge of how to use it.†

Limitations on Structural Material and Placement. Because the total supply of energy may depend sensitively on the successful use of convertible isotopes and the desirable supply of isotopes other than the fissionable ones appears to constitute no drain, an obvious objective of the design of nuclear reactors is the elimination of structural materials which capture neutrons, but are not themselves convertible isotopes. This objective implies a severe limitation on admissable structural materials, a limitation more restrictive than that which follows from the requirement that the chain reaction shall proceed.

The requirement that the chain reaction shall proceed is, of course, ever present. When other materials have been eliminated, it still affects the distribution of fissionable and convertible isotopes in the chain reactor. For example, if too much convertible isotope is mixed with the fissionable isotope too many neutrons will be captured in the convertible isotope and not enough will be left to maintain the fission–neutron cycle. Of course a simple solution of this problem can be obtained by removing the convertible isotope to the outside of the region in which the major chain reaction goes on. The extra neutrons eventually must escape to the outside where they may be trapped.

Critical Size and Control Problems. Even if a mixture containing fissionable isotope does not contain too much nonfissionable neutron absorber, it will support a chain reaction only if it occupies a sufficiently large volume. Neutrons escaping from the reactor are eliminated from the chain reaction whether they are extra neutrons or not. It is necessary, therefore, to adjust the fractional leakage so that only extra neutrons leave the reaction. This condition gives a critical volume,* beneath which a chain reaction will die away.

If the volume is raised above the critical one the extra neutrons will not all leak out, and their presence in the reactor will cause extra fissions and again more extra neutrons. As a result the power level will rise continually. The problem of controlling a chain reaction is therefore the problem of maintaining critical conditions or of inducing small deviations from such conditions to raise or lower the power level.

This problem would be extremely delicate, since there are normally very many fission–neutron cycles per second, were it not for the existence of so-called delayed neutrons as result of the fission process. Fortunately approximately half a per cent of the neutrons do not become free in the reactor immediately on fission. Instead they appear at a mean time of about ten seconds after fission has taken place.

The delay in appearance of these neutrons is a stabilizing influence on the chain reaction. Because the delayed neutrons will contribute to the fission rate in a way appro-

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*The importance of convertible isotopes in regenerating nuclear fuel has been emphasized by J. D. Cockcroft.[5,6] (See Appendix I.)

† There is no intention here of belittling the problems of extracting radioactive isotopes in usefully pure forms. The point is that present extraction techniques and low power levels for nuclear reactors are adequate to give an enormous isotope supply by current standards.

* The density of the constituents and relative dimensions are assumed fixed. If the density is changed the critical volume varies inversely with the third power: the critical mass thus goes as the inverse square of the density. If only the density is fixed the minimum volume corresponds to a spherical reactor.

priate to maintaining the power level of past operation, a small deviation from the critical size will not cause an immediate collapse or explosion of the reaction.

Time Behavior Patterns. The time behavior pattern when a small deviation from critical conditions is induced then will be roughly as follows: The reaction will respond immediately through the rapid sequence of fission-neutron cycles in which the prompt neutrons (those released without delay) enter; but, if the reactor is slightly too small, as the power level moves away from its old value too many delayed neutrons will be fed in from previous fissions to allow the fall to continue with the prompt neutron cycle speed. The rate of fall thus will be checked after the initial drop and further decrease in the power level will take place at a rate determined by the delay time, and the defect in reproduction when all neutrons are considered, both delayed and prompt.

Similarly if the reactor is too large, the power level will rise with extreme rapidity at first, but then slow down as the lack delayed neutrons at the new power level holds back the fission rate.

In the latter instance, however, another possibility is clear. If the size is too large, enough prompt neutrons will remain in the reactor to eliminate the necessity for delayed neutrons in the fission-neutron cycle. Changes in the intrinsic reactor properties or the over-all reactor size which increase the actual size over the critical one by such an amount would be disastrous. Control is easy enough as long as near critical conditions are maintained, but as there is only half a per cent of delayed neutrons we cannot afford to exceed critical conditions by a great amount.

Changes in Critical Conditions and Mechanisms of Control. A control system must be maintained to change the effective size of the reactor not only to be able to specify and to change the power level, but also to maintain the level in the face of variations in the intrinsic reactor proportions. For example, temperature and pressure affect the neutron fission cycle by changing densities and by shifting the equilibrium energy of free neutrons.

They enter the control problem in the short run. Their effect may be neutralized by changing the leakage through changes in the geometry, density, or neutron absorbing properties of the pile. Holes may be opened literally to let out neutrons, or control rods may be inserted. When temperatures and pressures return to their old values the reactor is returned to its old configuration.

There are other effects on the time behavior, effects of which are cumulative or of long duration. Although convertible nuclei may help maintain fissionable isotopes, the fission products eventually replace the fissionable nuclei, substituting absorption for reproduction of neutrons. Unless the composition of the reactor is re-established by chemical processing and refabrication, neutron economy will suffer and critical sizes will shift. Some leeway must be left in the control system to accomodate this shift.

This type of reactivity change will be largely a function of the total energy released in the reactor. If all isotopes were stable, this certainly would be the case; but the existence of radioactive isotopes, and the reactor will be full of them, implies some dependence on the exact pattern of operation. Although the chain reaction be turned off, radioactive decay will continue to change the isotopic composition, and the reactivity will be a function of the shutdown time.

ELEMENTARY MATHEMATICAL THEORY OF TIME BEHAVIOR

The delayed neutrons following an instantaneous burst of fissions appear in a distribution in time which may be represented by

$$\sum_i \beta_i \lambda_i \epsilon^{-\lambda_i t}$$

where t is the time after fission. Approximate values of β_i and λ_i are given in Table I.* $\sum_i \beta_i = \beta$ is the fraction of all neutrons which thus is delayed.

To get a more detailed understanding of the time behavior of a nuclear reactor while avoiding unnecessary complexity, consider a simplified case in which

$$\sum_i \beta_i \lambda_i \epsilon^{-\lambda_i t}$$

is replaced by the single term

$$\beta \lambda_d \epsilon^{-\lambda_d t}$$

For a single delayed neutron decay constant λ_d to replace the half dozen λ_i actually observed is not possible in general. Over a restricted range of time behavior patterns, however, a λ_d can be chosen to give a practical, as well as illustrative, approximation. Such a value would be about $\lambda_d \approx 0.1$ second^{-1} for most problems.

If k is the number of fissions that would result from the neutrons liberated in a single fission in a uniform nuclear reactor of infinite extent and if L is the fractional leakage of neutrons in a finite system, $k(1-L)(1-\beta)$ is the fractional number of fissions produced by the neutrons released immediately and $k(1-L)\beta$ the fractional number of fissions which are effectively delayed after a given fission. The rate at which these delayed fissions take place at any time is determined by the number of delayed neutrons, N_d, which have accumulated divided by the mean time of delay $1/\lambda_d$, that is, $\lambda_d N_d$; by the value of $k(1-L)$; and by the number of neutrons per fission, η. Consequently, the rate of fission R is given by

$$R = k(1-L)[(1-\beta)R + \lambda_d N_d/\eta] \tag{1}$$

As the difference between the rate of production and the

* The λ_i probably are determined by the radioactive decay of certain fission fragments—those fragments which emit neutrons after radioactive disintegration. The β_i then are interpreted as the fractional numbers of such fission fragments resulting from a large number of fissions.

Table I. Delayed Neutron Characteristics

β_i	λ_i, sec^{-1}
0.0002	0.0125
0.0014	0.0315
0.0018	0.154
0.0020	0.452
0.0007	1.64

rate at which delayed neutrons become free gives the rate of increase of N_d

$$\eta\beta R - \lambda_d N_d = \frac{\partial N_d}{\partial t} \tag{2}$$

Note that when $R=0$, $N_d = C\epsilon^{-\lambda_d t}$ in agreement with the time behavior assumed for delayed neutrons. These equations may be solved by

$$R\frac{\beta\eta}{\lambda+\lambda_d} = N_d$$
$$= N_d(0)\epsilon^{\int_0^t \lambda dt}$$

where λ is found by solving

$$k(1-L)\left[1-\frac{\beta\lambda}{\lambda+\lambda_d}\right]=1 \tag{3}$$

and $N_d(0)$ is the value of N_d at $t=0$. If

$$\mathfrak{E} = \frac{k(1-L)-1}{k(1-L)}$$

sometimes called the reactivity, is introduced

$$\mathfrak{E}/\beta = \frac{\lambda}{\lambda+\lambda_d} \tag{3a}$$

and

$$\beta\eta\, R = \frac{\lambda_d N_d(0)\epsilon^{\lambda_d \int_0^t \frac{\gamma}{1-\gamma} dt}}{1-\gamma} \tag{4}$$

with $\gamma = \dfrac{\mathfrak{E}(t)}{\beta}$.

Also certain conclusions now follow immediately:

1. When $\gamma=0$, $k(1-L)=1$ on the one side and $\beta R = \lambda_d N_d(0)$ on the other side—both obvious conditions for a stationary state—$L=(1/k)$ is the adjustment of fractional leakage which is necessary.

2. As $\mathfrak{E}$ increases to β, the fission rate goes to arbitrarily high values and so does the rate of rise of the power level. They go as $\dfrac{1}{1-\gamma}$ and as $\dfrac{1}{(1-\gamma)^2}$ if a sudden change in γ is made. The explanation is that when γ is equal to or greater than one [this is $k(1-L)(1-\beta)\geq 1$] the reaction can proceed entirely without delayed neutrons.

3. The delayed neutron emission is continuous even if γ has a discontinuity, but the fission rate (power level) will jump. The ratio of the fission rates before and after the jump is given by

$$\frac{R_{\text{after}}}{R_{\text{before}}} = \frac{1-\gamma_{\text{before}}}{1-\gamma_{\text{after}}}$$

Changes in Critical Conditions and Mechanisms of Control. These conclusions which were discussed nonmathematically in the previous section do not require the analysis used, but equation 4 also can be used more generally. For example, the behavior of control systems in which γ is coupled to the power level or its derivative can be studied. The stability of such control systems can be investigated and designs can be made to meet the requirements which may be imposed by fluctuations or systematic changes in pressure and temperature.* As a simple example small forced oscillations may serve.

If $\gamma = \alpha \sin \omega t$ and α is very much less than one, equation 4 becomes

$$\frac{\beta\eta R}{\lambda_d N_d(0)} = \frac{\epsilon^{\lambda_d \alpha\left(\frac{\cos \omega t - 1}{\omega}\right)}}{1-\alpha \sin \omega t}$$

which in turn gives

$$\frac{\beta\eta R}{\lambda_d N_d(0)} \approx (1-\alpha \tan \delta) + \alpha \frac{\sin(\omega t + \delta)}{\cos \delta}$$

with $\tan \delta = \lambda_d/\omega$, under the additional condition that α is very much less than ω/λ_d.† It should be noted that the model from which equation 4 followed is not good for any phenomena which involve frequencies of the order of the mean frequency for successive "immediate" fissions. Such phenomena, however, easily are included in a general treatment.

THE RELATION OF THE REACTIVITY TO SIZE AND INTRINSIC PROPERTIES OF THE REACTOR

The preceding section related the time behavior to the reactivity; and the reactivity was defined by the reproduction constant k and the fractional leakage L. We now examine the problem of relating the fractional leakage from a chain reaction, the size, and shape of the reactor to its intrinsic properties. The treatment will be restricted to the case of a reactor which is a single homogeneous region in space.

The Steady State. Suppose that a single fission takes place in an infinite region with properties identical with those of the reactor. The fissions which result from the neutrons given off will be distributed in space as some function of the distance r from the position of the initial fission, say $kK(r)$.

The fission rate, at one point, if the power level is constant, now can be related to the rate at all other points by

$$R(x,y,z) = k\int R(x',y',z')K\left(\sqrt{(x-x')^2+(y-y')^2+(z-z')^2}\right)dx'dy'dz' \tag{5}$$

(As k is the total number of fissions which result from the neutrons released in a single one, and therefore $4\pi\int K(\rho)\rho^2 d\rho = 1$.)

Even if k is greater than one, formal solutions of this equation can be found. They will have the property, however, that the fission rate cannot be positive throughout all space. Consequently, they cannot represent physical conditions in an infinite reactor. Fortunately, however, they will do a more useful job. Because the actual reactor will maintain a positive fission rate only over a finite region, they can represent the rate in a finite reactor. Such a solution corresponds to the use of image theory much like that used in electrostatics. Positive and

* The full description when $\Sigma_i \beta_i \lambda_i \epsilon^{-\lambda_i t}$ is used to describe the delayed neutron behavior is not so simple, but the main features are unchanged. When γ is a constant a general solution for any initial conditions can be constructed by superposing solutions of the type discussed. The relevant values of λ are the roots of

$$\gamma = \mathfrak{E}/\beta = \frac{\lambda}{\beta}\sum_i \frac{\beta_i}{\lambda+\lambda_i} \tag{3b}$$

For more difficult problems the Laplace transform method of solution has several advantages.[8,9]

† A rigorous solution of equation 4 also can be given for this case which need not be limited by the conditions $\alpha << 1$ and $\alpha << \omega/\lambda_d$. For example, rigorous treatment shows that in general the reactor does not oscillate about a steady level, but rises over a long time if it is oscillated about $\gamma=0$. This result also can be gotten from the next approximations in α, as $\epsilon^{\lambda_d \alpha^2 t/2}$, which is correct for small α.

negative neutron sources are used rather than positive and negative charges. The boundary condition which is met is that the fission rate shall fall to zero at the edge of the reactor.‡

Examples of the Power Density Distribution. The program described will be carried out for a reactor which is built as a rectangular parallelopiped of dimensions a, b, and c in the x, y, and z directions.**

Assume that

$$R=\sin\frac{\pi x}{a}\sin\frac{\pi y}{b}\sin\frac{\pi z}{c}$$

(where the origin of the co-ordinates is at one corner of the pile) as is in fact the case: It can be made up of a superposition of functions of the form

$$\epsilon^{j(\kappa_x x+\kappa_y y+\kappa_z z)}$$

If, the latter form is substituted for R in equation 5 the result is

$$\frac{1}{k}=\int\epsilon^{j(\kappa_x\xi+\kappa_y\eta+\kappa_z\zeta)}K(\sqrt{\xi^2+\eta^2+\zeta^2})d\xi d\eta d\zeta$$

where ϵ, η, and ζ are co-ordinates and have no relation to the same symbols as used elsewhere in this article. This form is equivalent to

$$\frac{1}{k}=4\pi\int\epsilon^{j(\kappa\rho)}K(\rho)\rho^2d\rho\frac{d\Omega}{4\pi}=1-\frac{\kappa^2}{3!}\overline{\rho^2}+\frac{\kappa^4}{5!}\overline{\rho^4}\ldots \quad (6)$$

Here

$$\overline{\rho^{2n}}=4\pi\int\rho^{2n}K(\rho)\rho^2d\rho$$

are the mean square, mean fourth power, and so forth, of the distance a neutron goes from fission to fission; Ω is the solid angle, and $\kappa^2=\kappa_x^2+\kappa_y^2+\kappa_z^2$.

For a steady state, equation 6 determines the admissible value of κ^2 say κ_0^2, but imposes no other condition. Because κ^2 is

$$\pi^2\left(\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}\right)$$

the possible critical dimensions are determined by

$$\pi^2\left(\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}\right)=\kappa_0^2$$

By using different superpositions of

$$\epsilon^{j(\kappa_x x+\kappa_y y+\kappa_z z)}$$

other possible distributions in space can be stated. To give one more example

$$R=J_0(\nu\sqrt{x^2+y^2})\sin\kappa_z z$$

is such a superposition. It is the distribution for a cylindrical reactor. For this case,

$$\kappa^2=\nu^2+\kappa_z^2$$
$$=\left(\frac{2.4048}{\text{radius}}\right)^2+\left(\frac{\pi}{\text{height}}\right)^2$$

and the critical conditions are

$$\left(\frac{2.4048}{\text{radius}}\right)^2+\left(\frac{\pi}{\text{height}}\right)^2=\kappa_0^2$$

where κ_0^2 is the solution of equation 6.

The Fractional Leakage and the General Case. In obtaining the critical size, the fractional leakage must be adjusted. Indeed, as $k(1-L)=1$ in a steady state, equation 6 may be interpreted in the terms of the fractional leakage L as

$$1-L=4\pi\int\epsilon^{j(\kappa\rho)}K(\rho)\rho^2d\rho\frac{d\Omega}{4\pi}$$
$$=1-\frac{\kappa^2}{3!}\overline{\rho^2}+\frac{\kappa^4}{5!}\overline{\rho^4}\ldots \quad (7)$$

But the fractional leakage is independent of the number of neutrons per fission, it depends merely on the distribution of fissions and the other characteristics of the reactor. Consequently, equation 7 is a general result for the leakage even if the reactor is not at critical size. In equation 7 the size and shape enter through κ^2 and the other reactor characteristics through $\overline{\rho^{2n}}$, the moments of $K(\rho)$. As a consequence of the general validity of equation 7

$$k(1-L)=4\pi k\int\epsilon^{j(\kappa\rho)}K(\rho)\rho^2d\rho\frac{d\Omega}{4\pi} \quad (8)$$

When it is noted that the reactivity $\mathfrak{E}=[k(1-L)-1]\div[k(1-L)]$, it is clear that equation 8 is the key result. It enables the relation of the time behavior studied earlier to the size and shape of the reactor and the intrinsic properties k and $\overline{\rho^{2n}}$.

Examples of the Leakage and of the Reactivity. For certain important special cases it is easy to evaluate the integral or sum the series in equation 7. When $K(\rho)$ is produced by the diffusion of neutrons without substantial change in energy it is well known that

$$K_d(\rho)=C\frac{\epsilon^{-\rho/Md}}{\rho} \quad (9)$$

with

$$M_d^2=\frac{1}{3!}\overline{\rho_d^2}$$

This leads to

$$1-L_d=\frac{1}{1+\kappa^2M_d^2}$$

Similarly for the slowing down of neutrons by elastic collisions

$$K_s(\rho)=C'\epsilon^{-\rho^2/4M_s^2} \quad (10)$$

with

$$M_s^2=\frac{1}{3!}\overline{\rho_s^2}$$

is a good approximation and

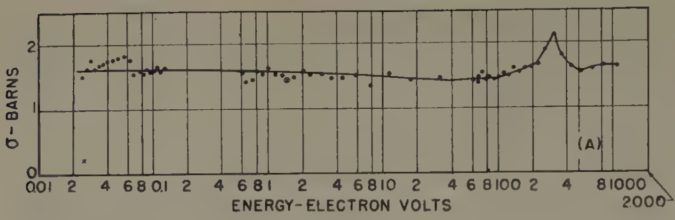
$$1-L_s=\epsilon^{-\kappa^2M_s^2} \quad (11)$$

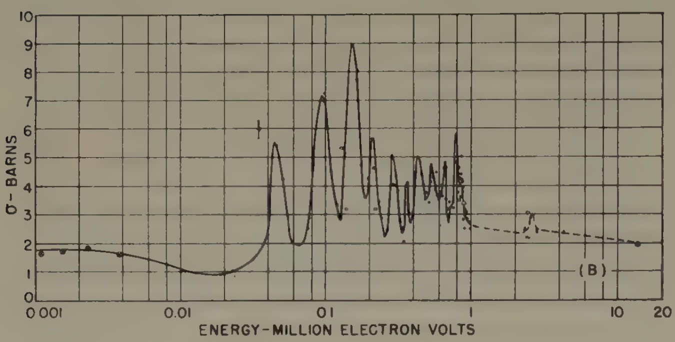
Finally, when such slowing down is followed by diffusion in thermal equilibrium

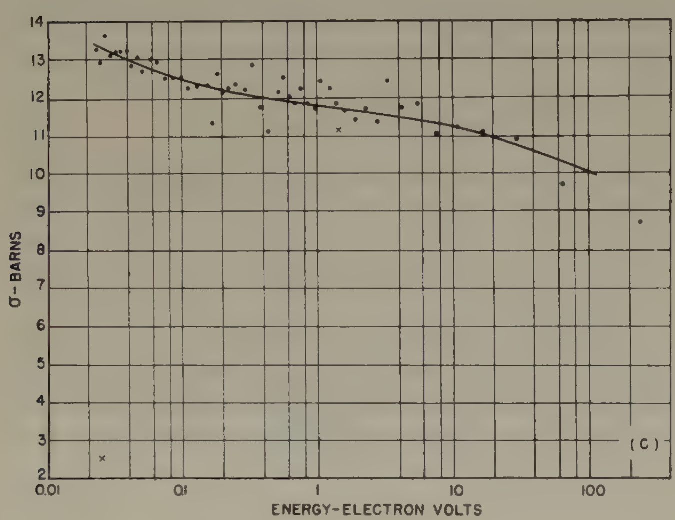
$$1-L=\frac{\epsilon^{-\kappa^2M_s^2}}{1+\kappa^2M_d^2} \quad (12)$$

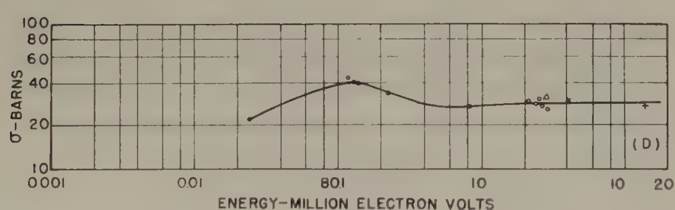
‡ This boundary condition is not quite accurate, but is a good approximation in most cases.[10]

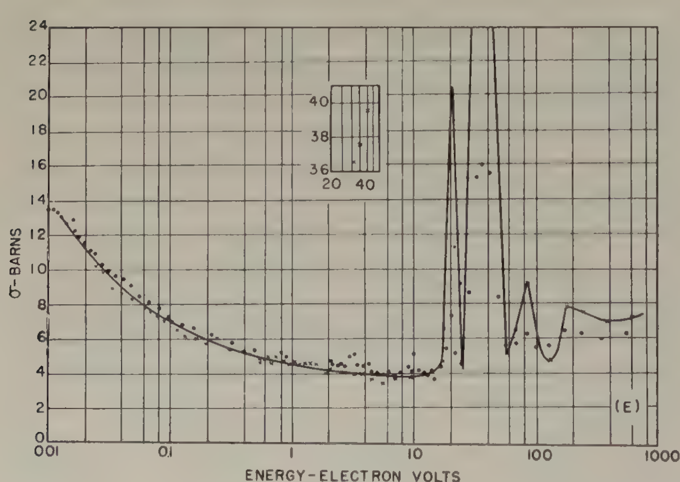
** A similar treatment has been given by Placzek and Volkoff.[11] It also is possible to use an alternative method.[8]











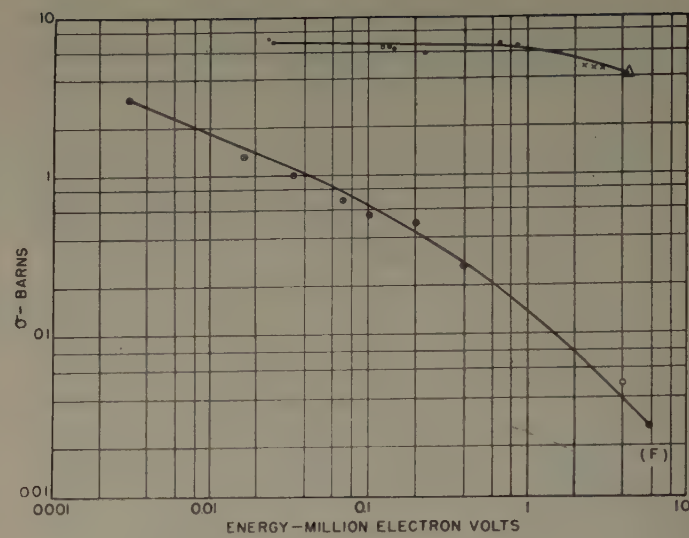


Figure 1. Typical cross section curves

σ_t is the total cross section and is equal to $\sigma_c+\sigma_{\text{deflection}}$. σ_c is indicated at 0.025 electron volt by an x. Usually the absorption cross section falls relative to the total as the neutron energy increases. σ_r on the curve for iodine is also the absorption cross section. Sharp peaks in the total cross section correspond to peaks in the absorption cross section for iodine but not for aluminum. The peak in the cross section for aluminum at 200 electron volts may result from manganese impurity. All cross sections are measured in barns (one barn is 10^{-24} square centimeter)

A—Al

- ● *Columbia velocity selector—unpublished*
- × *Hanstein—PR 59, 489 (1941)*
- ⊗ *J. Marshall—PR 70, 107 (A) (1946)*

B—Al

- ⊗ *Columbia velocity selector*
- ● *L. W. Seagondollar and H. H. Barschall—PR (publication pending). The solid curve follows these data*
- □ *Fields—PR 71, 508 (1947)*
- Φ *D. H. Frisch—unpublished*
- Δ *Good and Scharff-Goldhaber—PR 59, 917 (1941)*
- × *McPhail—PR 57, 669 (1940)*
- ○ *Aoki—PPMSJ 21, 232 (1939)*
- ▽ *Zinn—PR 56, 260 (1939)*
- + *Dunning—PR 48, 265 (1935)*
- ⊕ *Amaldi—unpublished*

C—Fe

- ● *Columbia velocity selector*
- × *Hanstein*

D—Fe

- ● *Fields*
- ○ *Aoki*
- Δ *Zinn*
- × *Dunning*
- + *Amaldi*

E—I. The shape of the curve between 30 and 40 electron volts indicates the presence of a number of resonances

- ● *Wu—PR 71, 174 (1947)*
- × *W. B. Jones—Cornell velocity selector, unpublished*

F—I. Lower curve is σ_r

- ● *Fields*
- × *Aoki*
- Δ *Dunning*
- ⊗ *Segrè—unpublished*
- ○ *Marshall and Szilard—unpublished*

As an example: the reactivity for the last case is*

$$\mathfrak{E}=1-\frac{(1+\kappa^2M_d^2)\epsilon^{\kappa^2 M_s^2}}{k} \tag{13}$$

An Approximation for Large Reactors. The expansion of $1-L$ in powers of κ^2 suggests that

$$-L=1-\kappa^2M^2$$

with

$$M^2=\frac{1}{3!}\overline{\rho^2}$$

will give a good approximation when $\kappa^2M^2<<1$. This is indeed a useful approximation for large reactors. In this case

$$\mathfrak{E}=1-\frac{1+\kappa^2M^2}{k} \tag{13a}$$

for any $K(\rho)$ which may be anticipated physically.†

This approximation shows clearly the physical features to be expected. The critical size is determined essentially by the length M and the excess of k over one. It is

$$V=G\frac{M^3}{(k-1)^{3/2}} \tag{14}$$

where G is a function of the shape alone (sphere, cube, and so forth).‡

THE INTRINSIC PROPERTIES IN TERMS OF CONCENTRATIONS AND FUNDAMENTAL NUCLEAR PROPERTIES

The chain reaction has been described by k and $K(r)$, the reproduction constant and the spatial distribution in an infinite region. The evaluation of k and $K(r)$, or, in the approximation for large reactors, k and M^2 is now desirable.

For some cases M^2 is experimentally measurable; but instead of describing the possible methods of measurement,[13] M^2 will be related to more fundamental parameters.

In problems involving a large number of flights in random directions

$$\frac{\overline{\rho_n^2}}{3!}=\frac{1}{3}\lambda^2N \tag{15}$$

where λ is the mean free path per flight (Note: this symbol has no relation to the λ previously used in equation 3) and N the number of flights.** In the reactor, the neutron mean free path λ is itself a function of the neutron energy; an appropriate generalization of $\overline{\rho_N^2}/3!$ is thus

$$\overline{\rho_E^2}/3!=\frac{1}{3}\int^{E}\lambda^2(E)dN(E) \tag{15a}$$

where E is neutron energy and E_0 is the neutron energy at emission in the fission process.

To obtain M^2, $\overline{\rho_E^2}/3!$ now must be averaged over the importance of the various energy ranges for the chain reaction in an infinite region. This importance is measured by that part of the reproduction constant which arises in the energy range. Consequently

$$M^2=\int_{E_0}^{0}\frac{\overline{\rho_E^2}}{3!}dk(E)/k \tag{16}$$

where

$$k=\int_{E_0}^{0}dk(E)$$

The Thermal-Fission Reactor. For example, if all fission takes place at thermal energy

$$M^2=\frac{\overline{\rho_s^2}}{3!}+\frac{\overline{\rho_d^2}}{3!}$$

and

$$k=\eta pf$$

where

$$\frac{\overline{\rho_s^2}}{3!}=\frac{1}{3}\int_{E_0}^{E_{th}}\lambda^2(E)dN(E)$$

$$\frac{\overline{\rho_d^2}}{3!}=\frac{1}{3}\lambda_{th}^2N_{th}$$

p is the probability that a neutron in an infinite region will survive the passage from fission to thermal energy, f is the fraction of all the neutron absorption processes at thermal energy which take place in the fissionable isotope, and η is the number of neutrons per fission. The subscript *th* means in thermal equilibrium.

The free path λ, the number of collisions $dN(E)$ and N_{th}, the survival probability p, and f the "utilization" of thermal neutrons in fissionable isotope, all can be expressed in terms of the concentrations (number per unit volume) of the nuclei, and some specifically nuclear properties.

As a neutron passes a single nucleus, it may be deflected from its path or captured by the nucleus. The effective area which the nucleus presents to passing neutrons is called the cross section and denoted by σ. The free path for a neutron traveling in a body of nuclei is given by $\lambda=1/(\mathfrak{N}\sigma)$ where $\mathfrak{N}$ is the concentration of the nuclei.

The propensity of a single nucleus to capture a passing neutron also may be expressed as an effective area, and the capture cross section for single fissionable and non-fissionable nuclei will be denoted by σ_f and σ_c. The utilization, f, then is given by

$$f=\frac{\sigma_f\mathfrak{N}_f}{\sigma_f\mathfrak{N}_f+\sigma_c\mathfrak{N}_c}$$

where $\mathfrak{N}_f$ and $\mathfrak{N}_c$ are the concentrations of fissionable and nonfissionable isotopes. Also the mean number of collision made by a neutron thermal equilibrium is given by

$$\frac{\sigma\mathfrak{N}}{\sigma_f\mathfrak{N}_f+\sigma_c\mathfrak{N}_c}$$

with the result that

$$\frac{\overline{\rho_d^2}}{3!}=\frac{1}{3\sigma\mathfrak{N}(\sigma_f\mathfrak{N}_f+\sigma_c\mathfrak{N}_c)}$$

Above the equilibrium energy a neutron which is deflected by a collision with a nucleus will transfer some

* For critical conditions, $\mathfrak{E}=0$, this equation was given some years ago by Fermi.[12,8]

† Mathematically pathological functions $K(\rho)$ of course can be constructed.

‡ In general if κ^2 is a solution of equation 6

$V=G/\kappa^3$

** Compare the theory of Brownian Motion, almost any treatment.

energy to the nucleus it strikes. The mean logarithmic energy decrement in such a collision is determined by the relative mass of neutron and nucleus. The number of collisions $dN(E)$ can be computed in terms of the logarithmic energy decrement, ξ,* (this ξ has no relation to the same symbol used previously to mean a rectangular coordinate), approximately

$$dN(E) = -\frac{d\log_e E}{\xi}$$

and thus

$$\frac{\overline{\rho_s^2}}{3!} = \int_{E_{th}}^{E_0} \frac{d\log_e E}{3(\sigma\mathfrak{N})^2\xi}$$

The remaining problem is the evaluation of p, the survival probability. In order to obtain p, consider $p(E)$, the survival probably from E_0 to E, where E is any energy between E_0 and E_{th}. The absorption of neutrons in a logarithmic energy range $d\log_e E$ at E is $-dp(E)$ times the number of neutrons starting at E_0. However, the absorption is given by the probability of survival to E and the probability that any neutron there is absorbed in the competition between absorption and energy loss as alternative ways that a neutron may leave the range $d\log_e E$. As the absorption is proportional to $\sigma_c\mathfrak{N}_c$ (σ_c evaluated for neutrons of energy E of course), and the number of neutrons lost by change in energy is proportional to $\sigma\mathfrak{N}\xi$, the result is

$$-dp(E) = p(E)\frac{\sigma_c\mathfrak{N}_c}{\sigma_c\mathfrak{N}_c + \sigma N\xi}\, d\log_e E.$$

The integral of this equation gives

$$p = \exp\left\{-\int_{E_{th}}^{E_0} \frac{\sigma_c\mathfrak{N}_c}{\sigma_c\mathfrak{N}_c + \sigma\mathfrak{N}\xi}\, d\log_e E\right\}$$

In principle, at least, the simple homogeneous reactor now has been described. Tables and graphs of the cross sections are available.[14] A few typical examples are plotted in Figure 1 and a graph of ξ as a function of the atomic weight is included (Figure 2). (The author wishes to express his appreciation for the graph which was supplied by Clark Goodman and the cross sections by B. T. Feld.)

Although the theory here outlined is incomplete it will serve to emphasize the main problems. The importance of reducing the nonfissionable absorption, $\sigma_c\mathfrak{N}_c$ in the reactor is shown clearly in the example of the thermal-fission reactor. Unless

$$\left(1 + \frac{\sigma_c\mathfrak{N}_c}{\sigma_f\mathfrak{N}_f}\right)/p < \eta$$

no reaction will run; a limiting value of $\sigma_c\mathfrak{N}_c$ is thus determined. As $\sigma_c\mathfrak{N}_c$ becomes smaller the critical volume is reduced, and the economic flexibility of the system increases.

The production of desirable isotopes by the utilization

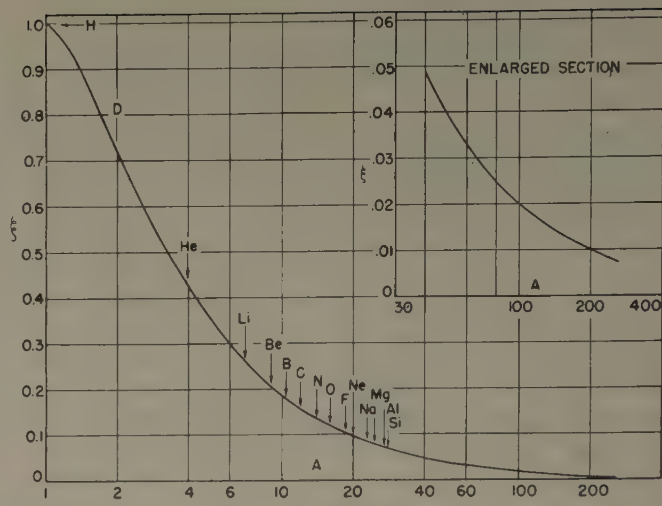


Figure 2. ξ versus A, the nuclear mass in units of the neutron mass

$$\xi = 1 - \frac{(1-A)^2}{2A}\log_e\left(\frac{A+1}{A-1}\right)$$

$$\xi \approx \frac{2}{A + {}^2/_3}\ (\textit{for large } A)$$

of extra neutrons will be feasible only if the nonfissionable absorption in the reactor is in the appropriate parent isotope or if the leakage of neutrons L is appreciable. For the latter case, the example of the thermal-fission reactor shows that

$$L = 1 - \frac{1}{\eta}\left(1 + \frac{\sigma_c\mathfrak{N}_c}{\sigma_f\mathfrak{N}_f}\right)$$

(Assuming $p=1$ for simplicity.) Because the maximum possible leakage is

$$L_{\max} = 1 - \frac{1}{\eta},$$

the resulting efficiency is

$$L/L_{\max} = 1 - \frac{(\sigma_c\mathfrak{N}_c/\sigma_f\mathfrak{N}_f)}{\eta - 1}$$

It is zero at the limiting value of $\sigma_c\mathfrak{N}_c$, because a reaction is barely possible then, and increases linearly as further indesirable absorber is removed.

The necessity of eliminating absorbing structural materials and the importance of frequent or even continuous removal of fission products thus is restated in a formal way by this theoretical treatment. At the same time this theory exhibits the essential elements of the problem of controlling the reaction rate.*

Clearly the restrictions upon structural materials also apply to working fluids used to extract energy from a reactor. Beyond this point the problem of converting the heat generated into electricity or piping it away for immediate use is one of conventional engineering, complicated by the requirements of shielding against the radioactivity produced.

* For any nucleus $\sigma = \sigma_c + \sigma_{\text{deflection}}$. It will be assumed, however, that in the reactor the total cross section of all nuclei, $\sigma\mathfrak{N} = \Sigma(\sigma)_i\mathfrak{N}_i$ where i denotes the various nuclei, is large compared with $\Sigma(\sigma_c)_i\mathfrak{N}_i$ (note that $(\sigma_c)_f = \sigma_f$ in this notation). Also

$$\sigma\mathfrak{N}\xi = \Sigma(\sigma)_i\mathfrak{N}_i\xi_i$$
$$\approx \Sigma(\sigma_{\text{deflection}})_i\mathfrak{N}_i\xi_i$$

* The effect of inserting a control rod is to change the boundaries of the reactor. In fact, a change in control rod position can be introduced in this theory as a change in κ^2; thus the time behavior can be computed when control rods are used.[8]

The problem of designing servomechanisms to control the reaction is similarly conventional as the role of the nuclear chain can be incorporated in the design of such a control system by use of the time dependent theory of the reactor. It is to be hoped that the day when the complete design of nuclear chain reaction in conventional engineering is not too far distant.

Appendix I

Since this article was written, the third semiannual report of the United States Atomic Energy Commission has been transmitted to Congress. In this report the commission states:

One important line of work in the direction of improved reactors is aimed at development of a "breeder" type of reactor. This is a nuclear chain reactor which over a period of time will actually create more fissionable material than is put into the reactor as fuel to sustain the reaction. . . .

The significance of the breeder type of reactor is directly related to questions of the stores of uranium and thorium in the earth's surface and the problems of their recovery and use, whether economic, political, or technological. Both the military and industrial potential of atomic energy justify the effort to solve the problems of "breeding." . . .

Because of the relationship between the rate of reproduction of fuel in a breeder and the power of the reactor, the development of breeders and of reactors for power will go hand in hand. There is, in effect, a complete interlocking of the scientific and engineering problems of the breeder and the power reactor, with both heavily influenced by our ability at any given time to produce, recover, and process efficiently and with reasonable economy the required fuels. . . .

The generation of significant amounts of useful power from nuclear energy depends upon no single factor of availability or utilization of fissionable materials, but upon a complex pattern of developments in the fields of exploration and processing of raw materials, reactor working materials, chemical separation systems, and reactor design and operating techniques. The development work to be done in these fields and the periods of time required to produce usable amounts of new fuel through "breeding" introduce a time factor measured in years into any discussion as to when nuclear energy can make a significant contribution to the supply of power now available from other sources.

The sections of this article dealing with the importance of convertible isotopes, the limitations on structural materials, and the desirability of chemical processing to eliminate accumulated fission produces are clarified and strengthened by these remarks of the commission.

In addition to the statements quoted here, the commission's report contains a clear presentation of the elements of many atomic energy problems which had to be slighted in the present article.

Appendix II. Symbols

α = maximum amplitude of forced oscillations
$\beta = \sum_i \beta_i$ = fraction of all neutrons which is delayed
β_i = fraction of all neutrons which is delayed in the ith group
$\gamma = \mathfrak{E}(t)/\beta$
$\delta = \tan^{-1} \frac{\omega}{\lambda_d}$
ϵ = base of natural logarithms
ζ = see ξ, for use with ξ and η
η = number of neutrons per fission
η = see ξ, for use with ξ and ζ
κ = constant determined by the size and shape of the reactor
κ_0 = permissible value of κ for steady state operation
λ = root of equation 3
λ = mean free path per flight
λ_d = decay constant of delayed neutrons
λ_i = decay constant associated with the ith group of delayed neutrons
ν = constant associated with first zero of J_0
ξ, η, ζ = co-ordinates locating a point
ξ = logarithmic energy decrement
$\rho = \sqrt{\xi^2+\eta^2+\zeta^2}$
$\rho' = \sqrt{\xi'^2+\eta'^2+\zeta'^2}$
ρ_d = root mean square distance traveled by neutrons in thermal diffusion
ρ_E = root mean square distance in going from fission to energy E
ρ_n = root mean square distance in n flights
ρ_s = root mean square distance in slowing down by elastic collision
σ = effective area of nucleus
Ω = solid angle
ω = angular frequency
$a, b, c,$ = dimensions of rectangular reactor
C = constant
c (as a subscript) = nonfissionable nucleus (which captures neutrons)
d (as a subscript) = with reference to delayed neutrons
$\mathfrak{E} = \frac{k(1-L)-1}{k(1-L)}$ = reactivity
E = neutron energy
f = fraction of all the neutron absorption processes at thermal energy which take place in fissionable isotopes
f (as a subscript) = fissionable nucleus
G = constant which is determined by shape and size of reactor
i (as a subscript) = the various nuclei, the various groups of delayed neutrons
J_0 = Bessel function of the 0th order and first kind
$j = \sqrt{-1}$
$K(r)$ = spatial distribution of fission from the neutrons coming from a single fission
k = number fissions in a uniform nuclear reactor of infinite extent resulting from neutrons liberated in a single fission (reproduction constant)
L = fractional leakage of neutrons in a finite reactor
$M = \frac{\rho^2}{3!}$ = characteristic length determined by intrinsic properties of reactor
N = number of flights
N_d = number of delayed neutrons
$\mathfrak{N}$ = concentration of nuclei
n = any integer (number of term in series)
p = probability that a neutron in an infinite region will survive the passage from fission to thermal energy
R = rate of fission
r = distance from position of initial fission
s (as a subscript) = with reference to slowing down of neutrons by elastic collisions
t = time after fission, time measured from arbitrary origin
th (as a subscript) = thermal equilibrium
V = critical size
x, y, z = co-ordinates of a point in a reactor
x', y', z' = co-ordinates of another point in a reactor
bar over quantity = average value

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Oil Production by Electric Power

W. G. TAYLOR

IT IS WELL KNOWN in the oil industry that no two oil wells are alike, therefore this article has been prepared to cover specific conditions affecting the application of electric power to the operation of producing wells, the selection of suitable electric equipment for this purpose, and the layout of electric power distribution systems in the oil fields.

Many oil wells flow naturally for a time after they are drilled. By means of electric control, the flow of the oil can be scheduled and timed automatically to meet such requirements as those of proration and filling of receiving tanks. At least ten operating methods are available to produce oil from wells which do not flow or have ceased to do so, and five of these are used to a considerable extent. Electric power readily is applied to all of these methods, usually in the form of motor drive for pumps or compressors.

Beam Pumping of Individual Wells. About 90 per cent of all pumped wells are producing by this method, which employs a power-driven pumping unit (Figure 1) incorporating a walking-beam to actuate a deep-well reciprocating pump by means of "sucker" rods. Induction motors are used for the drive, and depending upon the conditions encountered, they may be of the normal-torque, high-torque, or high-slip type. Horsepower requirements are estimated readily.

Central-Power Pumping of Wells in Groups. In this method, a central power-driven unit (Figure 2) actuates pull rods extending to the wells to operate the deep-well pumps. Wells which are small producers often are pumped by this method, and standard induction motors are used for the drive.

Gas Lift. Natural gas or air, delivered by induction-motor-driven compressors, blows the oil out of the well in this method of production.

Centrifugal Bottom-Hole Pumping. This is exclusively an electrical application, using a submersible unit, consisting of motor and centrifugal pump, which is lowered into the well.

Hydraulic Pumping. Oil is lifted by a deep-well reciprocating pump actuated by oil under pressure, which is delivered down the hole by a motor-driven pump at the surface.

Water Flooding and Repressuring. Water flooding is a secondary recovery method, in which water at high pressure is injected into the oil-bearing formation to force the oil to neighboring wells which are pumped. There are many applications for electric drive in a water-flood system. Natural gas stripped of condensates is returned, in many fields, under pressure to the oil-producing formation to prolong or increase well flow. Such a repressuring system involves many electric drives and may use steam-turbine generating equipment.

Digest of paper **48-150**, "Oil Production by Electric Power," recommended by the AIEE chemical, electrochemical, and electrothermal committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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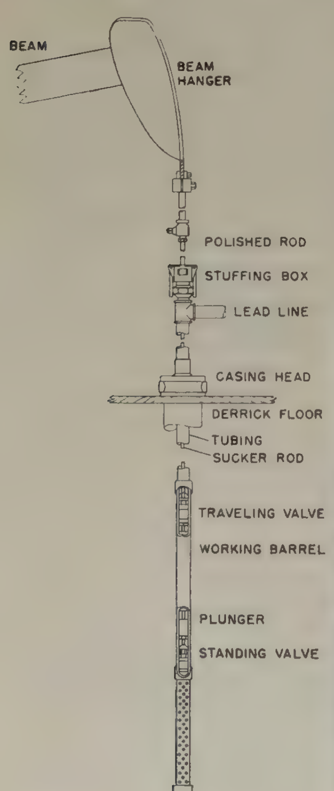


Figure 1 (left). An oil-well beam pump

Figure 2 (below). A central-power pumping setup where the power from a single motor is transmitted mechanically to a group of wells through a pull-rod system

Approximately two-thirds of the cost of electrification of an oil field is for the power-distribution system. This offers the best opportunity to effect economies in electrification, and it is therefore important that care be used in making a layout of the system. The factors involved are permissible voltage drop, number and sizes of motors, well spacing, configuration of the field, pole spacing, size and type of line wire, power factor, service reliability, and system costs. Of these, voltage drop is the main consideration.

The permissible voltage drop is based on the requirements of good practice in providing voltage at the motor within definite limits, making due allowance for motor starting conditions. The load-center principle of power distribution is recommended. Calculation of the many voltage drops in a system is simplified by using the "unit-load–unit-length" principle.

Single-phase transformer units are preferable. Because *Y*-delta or delta-*Y* transformer connections have some specific disadvantages, a delta-delta connection should be selected if possible. Capacitors are useful, not only to improve the normally low power factor of an oil-field load, but also to reduce voltage drop. They are located at the motors or on the feeders, depending on circumstances. Aluminum and copper conductors each require due consideration to determine which will meet the conditions best.

Digests of Conference Papers of North Eastern District Meeting

These are authors' digests of most of the conference papers presented at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. The papers are not scheduled for publication in AIEE *PROCEEDINGS* or in AIEE *TRANSACTIONS*.

Selection of Electric Drives for Looms; *R. J. Demartini, A. F. Lukens (General Electric Company, Schenectady, N. Y.).*

The occasion for preparation of this paper on loom drive applications was the completion of a series of tests directed at securing performance data upon which to base the design of a new line of cast frame loom motors. In the process there was afforded an opportunity to review testing methods used in the past and to develop new short cuts.

The loom load has a pulsating characteristic, and this factor largely determines the mechanical and electrical features required in a loom motor. The drive must be capable of operation without excessive speed variation on this load and must impart to the loom what a fixer refers to as the proper "feel." Its breakdown torque must be great enough to insure successful operation during the loom break-in period and under occasionally encountered low line voltage conditions. It must be totally enclosed to protect itself against the possibility of plugging with lint. The motor frame temperature should be held below the level at which it affects adversely the woven fabric. Finally, its component parts, particularly its bearings, must be capable of withstanding the peening effect of the loom pulsations.

In the proposed mathematical method for analyzing the loom load, each mechanical motion is considered and is defined by a mathematical expression. From these may be derived formulas to permit calculation of characteristics required of a motor to drive a specific loom. Thus, from a knowledge of the physical constants of a loom it is possible for the motor manufacturer to employ these formulas to select the proper motor for the job. The necessity for extensive trial and error testing is eliminated.

Occasionally mills compare motors on the basis of the relative magnitude of power input readings, accepting differentials as small as five to ten watts as a measure of comparative efficiency. Tests have proved that the friction losses in a loom may vary as much as 15 to 20 per cent within minutes. Furthermore, motor manufacturing tolerances may exceed the amount of differential accepted as conclusive evidence of superiority. Hence, in interpretation of test results the data must be corrected to refer to a common friction component.

The addition of flywheel in many loom applications may have the effect of reducing speed variation and watts loss and improving power factor. Furthermore, by adding flywheels to 6-pole motors, their performance on the loom may be made equivalent to that of 4-pole machines. As motors equipped with flywheels are now commercially available, every loom application should be studied in terms of the possible gains to be had from increasing the inertia of the drive system.

Minimizing Fire Hazards in Electric Equipment on Looms; *C. F. Hedlund (Associated Factory Mutual Fire Insurance Companies, Boston, Mass.).*

The fire hazard from defects in electric wiring and equipment is much more severe in a cotton mill where lint or loose cotton is always present than it is in other occupancies of average hazard. Statistics compiled by the Associated Factory Mutual Fire Insurance Companies show that of all the fires which occur in the industrial plants which they insure, 19 per cent are attributable to electrical causes. The loss experience for the period from 1938 to 1946 inclusive shows that 25.5 per cent of all these electrical fires occurred in cotton mills which represent only about ten per cent of the total business of the Factory Mutuals.

Investigation of many of the losses for the period 1935 to 1945 showed that the principal factors contributing to the failure of the electric equipment were vibration, improper and inadequate maintenance, poor installation, use of improper devices, and abuse. Loom motor switches caused most of the fires on plain looms. Other fires occurred from defects which developed in the loom motors, wiring between the loom motor switch and the motor, lighting equipment, and electric stop motions.

Further improvement by the manufacturer in the design of the enclosure for the loom motor switch is desirable. An enclosure the equal of the National Electrical Manufacturers Association *I-A* semidusttight type would be most acceptable if one were available at reasonable cost.

The use of flexible armored cable with ordinary insulated conductors and ordinary squeeze connectors, which conventionally is employed as the wiring method between the loom motor switch and the motor, is considered hazardous where vibration is severe. Oil and moisture resisting flexible cord such as the type *SO* with watertight connectors is advised as a more safe method requiring less maintenance. Flexible armored cable also is considered satisfactory if connectors such as the Thomas and Betts "Tite-Bite" type are used and conductors having an oil and moisture resisting insulation are installed under the cable. Vibration tests have shown the Tite-Bite connector to be satisfactory for this purpose.

Most of the fires caused by defects in the electric equipment on looms are preventable. The following safeguards will help to keep these fire losses at a minimum.

1. Loom motors of the totally enclosed type only should be used.

2. Wiring between loom switches and loom motors should consist of either the type *SO* flexible cord with watertight connectors, or flexible armored cable with Thomas and Betts Tite-Bite connectors, or their equal, and oil and moisture-resisting conductors.

3. Keep motor starting switches tightly closed, clean lint from interior periodically, keep connections tight, provide overload relays of proper size, and locate switch where it is not exposed to oil drippings.

4. Provide vaportight globes or covers over lamps under looms or within seven feet of floor if above the looms. Lighting fixtures should be installed permanently and wiring under looms should be in rigid conduit and pendent fixtures should be pipe pendent type. Control the lights by means of canopy switches, separate ceiling switches, or wall-type switches—chain pull or key-operated lampholders of the brass-shell paper-lined type are hazardous.

5. Extension lamps should be provided with vaportight globes, the cords should be type *SO* or equivalent, and attachment plug and receptacle should be the arc-confining type similar to Crouse-Hinds "Ark-Tite" type.

6. On electric stop motion equipments the voltage of the circuits should be maintained at no higher than 12 volts direct current and 14 volts alternating current. Tough oil-resistant wire should be used for the wiring on the loom frames, it should be well fastened and installed so that it cannot be damaged easily. Soldered lugs or patented connections should be used on all terminals. Circuits should be fused properly and the transformer and fuse enclosures should be kept tight and clean.

Slasher Drives; *C. E. Center (Westinghouse Electric Corporation, Boston, Mass.).*

Slashing is a textile process whereby a protective coating, or "sizing," of starch or other compound is applied to the strands of warp preparatory to weaving. This sizing minimizes friction and breakage in the loom. In good slashing the yarn stretch and tension must be controlled by the driving mechanism to assist the processes of applying the sizing and subsequent drying to retain resilience, avoid brittleness and weakness, and impart the proper "feel" to the warp.

From 4 to 20 rolls, each containing several hundred threads, called "ends," supply yarn which is carried in a sheet through the hot sizing, thence between squeeze rolls and into a dryer. This may be of the cylinder or hot air types. The warp then is pulled by a delivery roll through a series of splitter rods and then wound up on the loom beam.

Older mechanical drives employ a squirrel-cage motor driving the whole machine through a pair of cone pulleys and set of back-gearing with ratchets to obtain a range of production speeds and a low "creeping" speed. The delivery roll, cylinder-type dryer, and size vat rolls all are connected by gears, belts, chains, and lineshaft. The beam is driven from the main gearing through a slip friction whose slippage increases as the beam revolutions per minute decrease in winding from empty core to full beam. Modern mechanical deives utilize adjustable speed transmissions between size vats and dryer and between dryer cylinders and delivery roll to control relative speeds and therefore yarn stretch. Similar transmissions provide production speed adjustment. A separate gearmotor with overrunning clutch replaces back-gearing to obtain creeping speed. Difficulties with such drives include:

1. Unsatisfactory winding tension as a result of uneven slip and "chatter" of friction clutch.

2. Abrupt acceleration resulting in excessive stretch and broken ends.

3. Non-adjustable creeping speeds.

4. Unsatisfactory control of stretch in wet yarn on older machines.

5. Excessive maintenance.

6. Lack of flexibility in meeting requirements of different types of yarn.

Electromechanical drives usually retain the mechanical methods of controlling stretch between sections, and the slip friction for winding the beam. They employ electrical methods of varying production speed over a

wider range, controlled acceleration and sometimes deceleration. Push button control also provides increased flexibility and permits easier tying-in of the drive with automatic moisture control equipment. Methods are introduced for decreasing the duty on the slip clutch.

Full electric "multimotor" drives, introduced about 1944, utilize an adjustable-voltage system with individual d-c motors or gearmotors driving the beam, the delivery roll, the dryer rolls on certain types of dryers, and the size vat rolls. Production speed, creeping speed, standstill and running tensions, and stretch control between sections are under the operator's control and instruments permit consistent performance. Creeping speed and acceleration and deceleration rates are preset but adjustable. Beam winding tension is maintained automatically by a Rototrol or electronic regulator, and more yards may be wound on each beam. Yarn resiliency, quality, and loom efficiency thus are improved.

Drive Requirements for Worsted Slashers; *Paul J. Wenzel* (*Bachman Uxbridge Worsted Corporation, Uxbridge, Mass.*).

Yarns which have not been plied, but in which the fibers lay parallel, require a protective film or coating to enable them to withstand the abrasion of the weaving process. While this film must be tough enough to stand the wearing action of the reed and heddles during weaving, it must also be flexible enough so it will not reduce the natural elasticity of the yarns, as this elasticity contributes equally with the strength of the yarn in obtaining high weaving efficiency. This film is known as size, and the process of applying it is known as sizing. Most sizes are starches derived from tapioca, wheat, potato, and corn, although some filament mills used gelatins.

The two types of machines used in applying size to yarns are the size dresser and the slasher. Most of the sizing today is performed on slashers.

A slasher consists of three integral parts. The size box, where the mixture is applied to the yarn; the drying section; and the front end, where the individual threads are separated from each other, run through a comb, and wound up on a loom beam ready for weaving. The conventional size tank consists of an emersion roll and two sets of squeeze rolls.

The path of the yarn sheet in most slashers after emersion in the size box is horizontal between each set of squeeze rolls. Some worsted mills apply two emersions to the sheet, the second one after the sheet has been partly dried. This commonly is known as the double-dip method.

Both contact and air drying have been used on slashers for a good many years. The cotton mills use mostly contact or conduction method, and the woolen and worsted mills use heated air radiating from steam coils. Light work can be handled more efficiently with contact drying than heavy work, because the moisture evaporated from the bottom part of the sheet must pass through the balance of sheet before it can escape. With any type of contact dryers, yarns contacting the cylinders are over-dried when the slasher is stopped for broken end repair or beam changes.

Woolen and worsted mills generally have used a type of slasher known as a "hot air machine." This type of a dryer consists of a series of steam coils enclosed in a cast iron box. The yarn sheet passes between the sets of coils, and is supported by fluted rolls at each end. The drying is accomplished by heated air radiating from the coils. This type of dryer has a paddle fan at the lower front end which induces new air into the enclosure, and an exhaust fan at the top which removes a certain portion of heated air. These machines have from 40 to 120 yards in the drying area according to the drying rate desired. A few other types of slashers are in existence in the United States today some of which are of foreign origin.

Infrared radiation has been publicized widely as a drying means for slashers. Cost of drying with infrared radiation is about ten times the cost of drying with steam, and while some complete infrared dryers have been constructed for slashers, most applications have been in the form of predryers attached to conventional machines where increased speed was desired without too much regard to costs. High-frequency drying is so costly its use cannot be considered in this application at the present time.

Good slasher performance can be evaluated best in the weave room. All warps leaving the slasher should have uniformity of size and moisture content, not only across the width of the yarn sheet, but throughout the entire warp. All warps should be wound with uniform tension and there should be no variation in the amount of tension or stretch to which the yarn sheet has been subjected during the sizing process. Various factors effect size content, such as speed of the yarn sheet passing through the size bath, or the level and temperature of the size.

Moisture content in yarns has a considerable effect on weaving efficiency. Cotton yarns become stronger as the moisture is increased, rayon and worsted yarns become weaker, but all yarns increase in elasticity with increased moisture content.

Normal moisture content for sized cotton yarn is from $7^1/_2$ to 8 per cent and for rayon and worsted 10 per cent. Moisture content in all yarns must be kept below the mildew point. Over-drying of yarns in the slashing process while not too injurious to some fibers is distinctly not beneficial to any fiber. Any modern designed slasher should have some means of instant cooling when the machine is stopped for end breakage repair or loom beam change.

Weaving tests show that better weaving results are obtained when the yarn has been subjected to the least amount of tension during slashing operation. Two per cent is considered a normal stretch for cotton and spun rayons. Filament mills desire a stretch of five to seven per cent. Stretch control is established by means of a speed relationship between the delivery roll at the front end of the slasher and the squeeze roll at the back end, and can be controlled either mechanically or electrically. This method of control has been accurate enough for all practical purposes, but can be affected by various outside causes, such as size viscosity and tension of the yarn sheet before entering the size box.

The front end of the slasher, in addition to the warp windup mechanism, also is used for separating the dried individual threads by means of splitter or breaker rods. In splitting the unbroken size envelope in the dry state, however, a considerable portion of the benefit of the size application is destroyed. The size film is ruptured and considerable tearing of the fibers takes place. Improved slasher design should permit the yarn separation to take place after sizing, but before entering the drying area. This separation should be maintained until the yarn is more than 50 per cent dry. This will eliminate a lot of the evils of the dry splitting method.

The windup of the warp on the loom beam is the last function of the slasher, but it is also a very important one. Uniform tension should be maintained throughout the entire winding operation. The amount of tension required for best results for various types of warps is determined by the feel of the skilled operator rather than by any mathematical formula. Tension ranges from 150 to 600 pounds pull for broad warps.

For a good many years, the slip friction was the only method used for controlling the tension in the windup operation, and performed satisfactorily until the advent of the larger flanges used on the loom beams. Considerable more slippage of the friction plates was required for a 28-inch diameter than the 20-inch flange. One method to reduce the amount of slippage was through the use of a dual friction, each driven through a separate gear ratio. This permitted the operator to reduce the amount of slippage by changing from one friction to the other when the size of the warp necessitated it. Another means of controlling slippage is through the use of a variable speed drive which keeps the rate of slippage constant throughout the entire winding operation. The use of the a-c–d-c drive eliminates the mechanical slip friction entirely.

One slasher can produce enough warps to take care of the requirements of 200 to 500 looms. With this in mind, it readily can be seen why slashers must be designed more than any other machines in a textile mill to give continuous production with a minimum of breakdown or maintenance.

An Automatic Line Voltage Regulator for Industrial Loads; *E. W. Vaughan* (*Superior Electric Company, Bristol, Conn.*).

A general trend in engineering is towards increased precision. This trend is made possible by the development of new techniques and refinements of older ones. In the electrical industry, need for power supply facilities of better regulation than normally can be expected from utility feeders often is encountered. Such needs are found on production test lines, life test racks, radio transmitters, and many others. Clearly a means of attaining improved regulation which can be installed by the user is necessary.

Some of the desirable characteristics of such a regulator are

1. Units must be available for commonly encountered line voltages such as 115, 208, 230, and 440 volts single phase; and 208, 230, and 440 volts three phase.
2. Units must have high operating efficiency and speed.
3. Sensitivity should be in the order of one or two per cent.
4. Units should not be frequency sensitive in the 50–70 cycle range.
5. Wave form distortion must be kept as small as possible, preferably zero.
6. Units must have good stability and life.
7. Units must be easy and simple to maintain.
8. Units must be as small and inexpensive as possible, consistent with high performance.

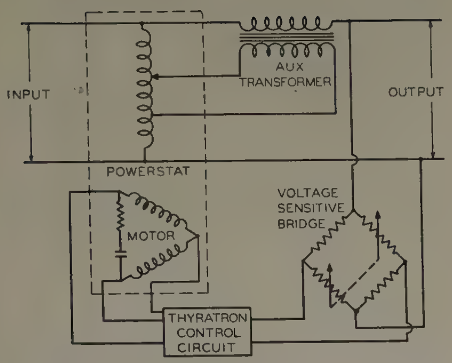


Figure 1. Block diagram of the regulator system

One way of satisfying these requirements is shown by the description of the type regulator which follows.

A line voltage regulator may be separated into three essential parts for purposes of discussion. They are

1. Error detector.
2. Amplifier and actuating mechanism.
3. Power control circuit.

Each part will be mentioned in turn. Error detectors for line voltage regulators are commonly voltage sensitive relays, ferroresonant circuits, thermal or voltage sensitive resistance arms in bridge circuits, and thermocouples. The bridge type of detector using a thermally sensitive resistance arm was chosen for this regulator for it offered the best performance as judged by the previously mentioned requirements.

The amplifier and actuating mechanism consists of a phase sensitive relay using two small thyratrons, and a slow speed synchronous motor. The signal from the error detector actuates the motor through the amplifier and causes the power control circuit to be adjusted by the motor in such manner that the output voltage is held constant.

The power control circuit consists of a fixed-ratio 2-winding transformer whose secondary is in series with one side of the line. The primary of this transformer is fed from a "Powerstat" variable voltage transformer with a voltage whose phase is either the same as or 180 degrees displaced from the incoming line voltage. Consequently, the output voltage of this circuit is the algebraic sum of the incoming line voltage and the secondary voltage of the fixed-ratio transformer. As block diagram of the regulator system is shown in Figure 1.

Electric Equipment for Plastic Injection Molding Machines; *Mark Morgan (Reed-Prentice Corporation, Worcester, Mass.).*

Electric equipment for plastic injection molding machines is of a greatly diversified nature. In particular, the unusual load curve of these machines calls for motors with special characteristics. A typical load curve is represented by Figure 2, where it appears that for a given machine, motor is underloaded during most of the cycle, except during the injection shot, when motor load rises to 250 per cent or more of name-plate rating. This means that "design *B*" motors are not always suitable: furthermore, selection of frame size is made not in relation to thermal capacity, but rather depending on breakdown torque available: motors usually employed are of low reactance type, with low starting torque, high starting current, very high breakdown torque.

Values of breakdown torques of standard motors of several manufacturers vary substantially from one to the other: this fact comes into play when safety margins are considered, in relation to the difficulty often encountered in practice because of heavy voltage drops at motor terminals during injection shot of the machine.

Next to the motor, vital in importance is the heating cylinder where plasticizing of the molding powder takes place: heat is generated by resistance elements of various materials and shape, tightly clamped around cylinder body; total wattages vary between 5 and 15 kw, depending upon machine size; that is upon amounts of plastic material to be plasticized per hour. In the design of a heater, not only total wattage is to be considered, but also distribution of the heating elements on the cylinder surface, and heat density in watts per square inch. Temperatures are critical with plastic materials and various types of pyrometer controllers are used, such as the millivoltmeter or the potentiometer, motor-driven or electronically operated, straight "off-on" or with regulated output. Thermocouples are of iron-constantan type and are placed near the outer surface of the heating cylinder, so that they do not measure the actual temperature of plastic material itself. This is an arbitrary way of measuring, as an error is introduced as a result of temperature gradient of the steel housing, which may be as much as two inches thick, however, the purpose of the temperature control system is more to hold temperature constant than to measure it, and results reached in practice are satisfactory.

The duration of the successive steps of the molding cycle shown on the graph is determined and controlled by four timers. The selection of suitable timers and the manner of incorporation in the electric circuit are important for trouble-free automatic operation. Guiding factors are current carrying capacity of contacts; life of timers measured in number of operations; flexibility of contact combinations for both load and holding contacts, such as momentary or sustained, overlapping or not, single or double pole, and normally open or closed. Plastic machines often are run automatically on a 24-hour-a-day schedule. Cycles are sometimes shorter than 20 seconds so it is clear that timers and other equipment must be capable of a heavy duty entailing millions of operations.

High-Frequency Circuits for Internal Grinding Machines; *Leroy B. Morrill (The Heald Machine Company, Worcester, Mass.).*

This paper deals with the application of high-frequency motors to grinding wheelheads together with a discussion of high-frequency circuit characteristics for such applications. Stators and rotors are "built-in" to the wheelheads and there arise a number of problems involved in assembly, cooling and bearing lubrication for such wheelheads operating at speeds up to 120,000 rpm.

Users of high-frequency equipment are divided into the following classifications:

1. The small user who requires one or two machine with wheelheads operating at fixed frequency.
2. The small user who has one or two machines with wheelheads operating at variable frequency.
3. The user who operates one or more groups of machines, each group from a common source of power.
4. The user who has high frequency wired throughout the plant.

Under the subject of high-frequency circuit characteristics, considering such topics as the output voltage to the motor at various frequencies, whether the source of power shall be 2-phase or 3-phase, and NEMA (National Electrical Manufacturers Association) standards for voltages and frequencies above 60 cycles together with present practice possibilities of overlapping voltages at the same frequency. It can be said that it is most necessary to establish circuit characteristics for high-frequency equipment, which will enable the user to operate similar equipment purchased from any machine tool builder from a single generator or source of high-frequency power. A solution to the problem has been found which eliminates the possibility of overlapping voltages by the proper use of some of the present NEMA standards and the elimination of others.

A few grinding machines now are equipped with 2-phase high-frequency wheelhead motors rather than 3-phase. The reason for this has been due largely to a difference of opinion on the subject amoung manufacturers of generating equipment. In this regard it is recommended that 3-phase be used. The whole subject now is being studied by interested machine tool and electrical manufacturers through their proper committees with the view of establishing a standard for circuit characteristics of high-frequency equipment for use with grinding and other metal cutting machines.

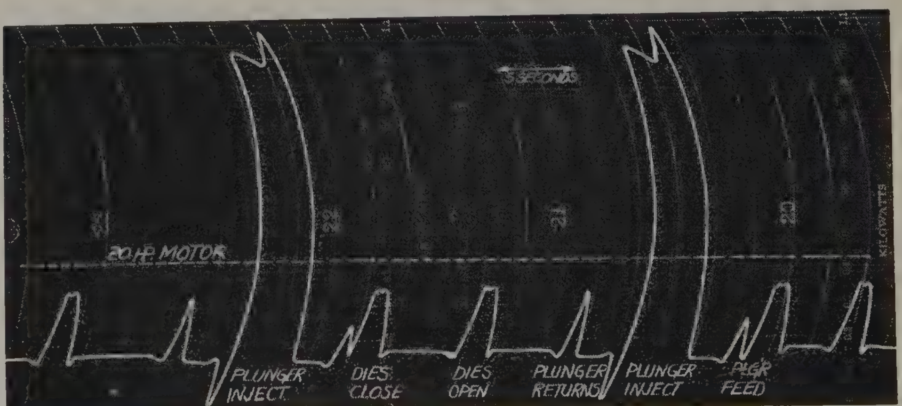


Figure 2. Typical load curve for a motor driving a plastic injection molding machine

A Philosophy of Power Pool Operation; *E. C. Brown (Connecticut Valley Power Exchange, Hartford, Conn.).*

A power pool is a device for co-ordinating the operations of two or more power systems so that the combined operation of the whole is cheaper and safer than the independent operation of the individual systems. These power pools perform two major functions—operating and accounting. Early attempts at pool operation indicated the need for a factual basis of charges and credits for the energy interchange which their operations produced. In 1925 the Connecticut Valley Power Exchange began operations based upon the following principles which offer a solution to this problem:

1. Inasmuch as all economy power is secondary power, each company shall maintain sufficient capacity to carry its load plus an agreed-upon reserve.

2. Each member company supplying energy to the exchange shall be reimbursed for the increase in out-of-pocket cost (incremental cost) it incurs in supplying this energy.

3. Each member company receiving energy from the exchange shall be charged the decrease in out-of-pocket cost (decremental saving) created by the receipt of this energy.

4. The capital charges on additional facilities made for joint operation shall be a first charge against the saving such facilities create.

5. The net savings remaining after the deduction of capital charges and the cost of operating the exchange shall be equitably divided among the member companies.

The exchange carries on its operating work through a small dispatching or load control office through which it endeavors to co-ordinate the operation of the facilities under its direction in the same manner that they would be operated if consolidated into one large system. The accounting work of the exchange is really a detailed application of the principles enumerated, to the energy interchange that has resulted from exchange operation. Exchange operations since 1925 have resulted in the interchange of 4.2 billion kilowatt-hours and have produced gross savings of 9.6 million dollars. The principles upon which the Connecticut Valley Power Exchange is based constitute a philosophy for power pool operations which has worked and is still working.

Highlights of Electric and Diesel-Electric Locomotive Operation; *P. H. Hatch (The New York, New Haven, and Hartford Railroad Company, New Haven, Conn.).*

A description of the electric and the Diesel-electric locomotive indicates that there are two major differences in these two types. One of these is that the Diesel-electric locomotive is independent of external power supply and can operate anywhere on a railroad subject to the limitation of its clearance diagram and its weight. The other major difference is that the electric locomotive, by being able to draw upon the capacity of the power system and by reason of design, can be made to possess high short-time overload capacity to permit accelerating and getting trains up to speed quickly, which has the effect of increasing the capacity of a railroad, traffic-wise.

The Diesel-electric locomotive lends itself to application wherever the characteristics and advantages of an electric locomotive are desired but where it would be difficult to justify the capital expense for the power distribution system. The electric locomotive, on the other hand, finds application where traffic density is high or other considerations are paramount and the investment involved therefore can be justified.

How Much Back-up for a Bus Protective Scheme? *J. M. Moore, C. A. Molsberry (The United Illuminating Company, New Haven, Conn.).*

English station of The United Illuminating Company has six 12,500-kw steam turbine-generators and six 13,800-volt bus sections. A 30,000-kw generator, and two bus sections with linear coupler protection, are being added. The bus fault protection will be extensively "backed up."

With this multiplicity of bus sections, normally no one section will serve more than one generator or more than one of several parallel feeders. As any one generator is "reserve" and any one of such feeders is a "spare," the importance of losing a bus section is minimized. This permits considering the new bus sections, adjacent bus sections, the new generator and its connections, and the outgoing feeders, as overlapping zones of protection as shown in Figure 3; and affording back-up protection for a faulted zone by tripping any adjacent zone which fails to be disconnected.

In case of a fault in any one of these zones, the back-up protection will provide for the failure to open of any one of the circuit breakers involved; except that, in the case of a fault on an ordinary outgoing feeder, outside of the reactor where the fault current is comparatively low, tripping a bus section seemed unduly drastic. In general, the back-up protection will consist of a separate time-delay relaying system; which will be initiated by the primary protection and eventually will trip an adjacent zone of protection through a "a"-switch on the onnecting circuit breaker, if closed.

The weakness of having the back-up protection so dependent upon the primary protection will be tolerated, and the hazard of the failure of any one relay to function will be accepted, without extensive duplication of protective devices; because:

1. The primary protection generally consistst of single phase elements, at least two of which could sense any kind of fault.

2. The continuity of the series "voltage differential" circuits acting on the linear coupler relay is so easy to check, that the test can be made as often as desired with the permanently installed equipment. The red indicating lamp at each circuit breaker control switch shows that its tripping circuit is intact. Where practicable, neon lamps will be connected to monitor other operating circuits.

3. The auxiliary relay associated with the linear coupler relays probably will be duplicated.

4. Careful installation and maintenance is expected at this important location.

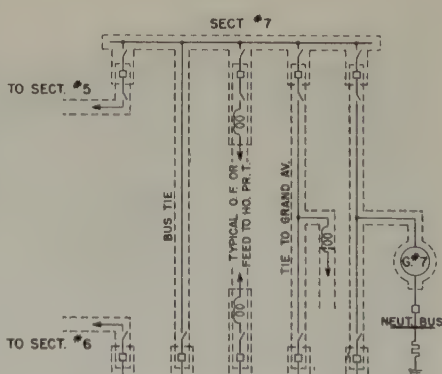


Figure 3. English station—zones of protection of new bus sections numbers 7 and 8

The additional "exposure" entailed by this back-up protection was considered the minimum commensurate with the risks involved; but was increased slightly to interlock against accidental false tripping.

Operating conditions in other properties might not admit of all of the compromises indicated. However, if further details on any elements of the scheme are desired, the authors of this paper will be happy to comply.

An Application of Carrier Relaying to a 3-Terminal 115-Kv Line; *V. J. Hayes (Connecticut Light and Power Company, Waterbury, Conn.).*

This 3-terminal line forms the only tie between two main generating plants, as well as an important supply line from both to the center of the system load area. A-c calculating board studies indicated that regulators having a ten per cent raise and lower range were needed at each terminal to provide adequate power transfer. Regulating auto transformers at each terminal connect the 115-kv line to the local 69-kv bus through 69-kv switching. The latter are 20-cycle 3-pole reclosing to obtain transient stability under maximum load transfer. To obtain maximum sensitivity to fault currents with lesser sensitivity to load currents, three zone modified impedance relays were used with high speed directional ground relays. The carrier frequency signal is used to block high speed tripping and is controlled by the second and third zone impedance elements. The first zone element trips independently of any carrier trip-blocking signal. The directional ground relays are polarized by the current in the tertiary winding of the line auto transformer. Back-up relaying consists of impedance relay timer elements, induction disk directional ground relays, and phase and tertiary winding overcurrent relays. Each auto transformer is equipped with differential relays, which directly trip the local circuit breaker and cause a carrier signal with superimposed audio frequencies to be sent to the remote terminals to trip the circuit breakers at these points.

Immediate automatic reclosing is employed at each terminal following line to ground faults, but following phase-to-phase faults which may not be cleared simultaneously at all three terminals, a short time delay automatic reclosing is employed at two terminals only to avoid instability.

The carrier set transmitter frequencies are approximately 100 kc with a 1-kc separation to prevent frequency drift from producing a beat note that might operate the audio tone receivers used in remote tripping. The receivers were tuned for best reception from the two remote terminals.

Staged fault tests using a phase-to-phase solid short circuit showed that the d-c component in the first few cycles caused excessive reach of the first zone elements of the impedance relays, necessitating a substantially lower setting to avoid overreaching a remote terminal for faults external to the carrier protected system. Line-to-ground staged

faults to check fault clearing and reclosing at first produced restriking of the arc, but by using number 41 copper wire as a fuse, successful clearing and reclosing were obtained.

Four line faults have occurred since putting the line into service, two being permanent-type faults in which the line switches correctly tripped, reclosed, and retripped. In the other two faults, all three terminals tripped and reclosed successfully in about 20 to 22 cycles to restore the ties.

Application of Limiters in Secondary Networks; *J. A. Rogoff (Burndy Engineering Company, New York, N. Y.).*

The limiter is a combined fuse and electric connector designed to provide short-circuit protection in underground secondary networks. The time-current characteristic curve of the limiter is co-ordinated with the cable insulation damage characteristic curve, so that the limiter will clear and provide protection for the cable before the cable insulation is damaged.

There are three principal types of limiters available. These are the standard 250-volt limiter, the 250-volt replaceable-link limiter, and the 600-volt high-capacity limiter. The standard 250-volt limiter is suitable for interrupting alternating current up to 30,000 amperes with minor disturbance and noise. If it is desired that this device interrupt current without any disturbance whatsoever, then the interrupting capacity should be considered to be half the foregoing value. Similarly the interrupting capacity of the replaceable-link limiter can be considered to be 20,000 amperes where some minor disturbance allowable, but only half that value where the interruption must be accompanied with no disturbance at all.

The high-capacity limiter can interrupt current, at 600 volts, up to 89,000 amperes and current in excess of 100,000 amperes at 250 volts. The operation of the high-capacity limiter is accompanied by no disturbance or violence whatsoever and therefore the interrupting capacity need not be derated for areas where any noise may be undesirable.

Ordinarily the standard 250-volt limiter is used in underground networks. However the fusible section for this limiter is fixed and is rated by cable size. In certain sections of the underground network, such as in outlying areas or where radial feeders are joined to the network, there may not be sufficient fault current available to clear a standard limiter. In such locations the replaceable-link limiter may be used as the fusible element of this type of limiter can be selected by current rating and a smaller fusible section may be selected to protect the cable. On the other hand in very heavily loaded sections of the network, it is desirable to have a limiter which will interrupt very heavy fault current without any noise or disturbance whatsoever. The high-capacity limiter is designed to accomplish this function.

In installing limiters in underground networks a careful consideration of their time-current characteristics and interrupting capacities should be made. It is not wise to decide arbitrarily on one type of limiter and make that standard for all applications. However, a choice among the various types that are available will provide suitable protection for cables installed in all of the various sections of the network.

Experience With High Speed Reclosing of Transmission Lines; *G. E. Dana (New York State Electric and Gas Corporation, Binghampton, N. Y.).*

This paper summarizes and analyzes the operating record of two 114-kv transmission lines equipped with 3-pole 20-cycle reclosing over a period of $2^1/_2$ years. Although several papers previously have been written describing the operating results obtained by high speed reclosing, they were based upon circuits well protected by overhead ground wires. The experience described in this paper is based upon the application of the same principle to high impulse wooden H-frame lines. Because both lines are of the same type of construction, but only one is equipped with overhead ground wires, a relative evaluation of the benefits of equipping such circuits with sky wires is shown. Reduced to a "trip-per-line-mile" basis the records show that a 90 per cent improvement in the number of outages can be obtained in this area without the use of a counterpoise.

Successful high speed reclosing was obtained in 78 per cent of all cases. Eliminating those cases where successful reclosure was impossible because of permanent faults and repetitive flashovers in which reclosing was not attempted, the record shows 84 per cent successful operation. Only one permanent fault occurred and was the result of an incorrectly formed compression splice. On two occasions a second fault, occurring a few seconds after a successful reclosing operation, could not be reclosed because the reclosing relay was denied sufficient time to reset.

During a portion of the time, a generating station with a small local load was connected to the system through a single circuit and was thus dependent upon the reclosing operation to maintain synchronism. During the remainder of the period, this station was held in synchronism by other tie lines. Approximately the same percentage of successful operations was obtained in both cases, indicating that no difficulty from the generator getting out of step was experienced.

Excessive generator shaft torque upon reclosure was investigated in addition to a stability study before making this application. A recent turbine generator inspection did not reveal any evidence of damage to the machine from the reclosing operation.

These points always should be checked before the application of high speed reclosing is made however. A similar installation now under construction will require that at least one other electrical tie, even though it be of much higher impedance, will be required to limit the transient shaft torque to the manufacturers guarantee.

Staged faults tests made after the installation was completed were found very useful. They showed some relay limitations and pointed out the means of correcting the same. Moving pictures made of the short-circuit tests were studied frame by frame and indicated that reducing the line de-energized period to less than the usual 12 cycles is not advisable.

Electrical Drives Found in Wire Mills; *Roger H. Bryant (American Steel and Wire Company, Worcester, Mass.).*

Experience shows that five operating states merit consideration when planning new installations and maintaining present ones:

1 *Machine and drive at rest.* D-c controllers should break both sides of line and should cut off shunt field when motor is not operating. As it is a custom to locate controllers in groups some distance from the machines it may be desirable to provide emergency tripping of feeder circuit breaker in case it is not possible to stop the machine by normal methods.

2. *Inching or jogging.* Machines such as multiple draft wire drawing machines on which considerable variation of size and kind of wire occurs, may need to have adjustable torque on the jogging point by permanently installed switches to bypass part of resistance. Adequate provision for jogging service should be made in choice of resistors, even to the extent of using resistors rated for continuous duy.

3. *Accelerating.* Definite time limit acceleration has proved entirely satisfactory, and there seems to be no reason for any more complicated systems.

4. *Normal running.* There is still room for improvement in overload protection. The usual type of thermal device is not too satisfactory as it often fails to give the protection desired while still permitting the maximum load on noncontinuous duty. As winding failure depends on the temperature attained, overload protection should be directly governed by winding temperature. It is hoped that more progress in that direction will be made in the near future. Demands from the operating department for increased speed should be referred to the electrical manufacturer with full information on increased load and speed desired, and his recommendations should not be stretched or unsatisfactory operation may result.

5. *Stopping.* Ability to stop when necessary and quicky enough to avoid damage or injury is essential. Dynamic braking, long in use on d-c motors, has worked equally well on 100- and 150-horsepower wound rotor motors. Plugging also has been found satisfactory on a number of smaller motors.

No matter how carefully the electric equipment may be chosen and installed, it must be borne in mind that keeping it clean and in proper adjustment will do more to prolong its life and keep up a high rate of production than any other method of maintenance.

Variable Voltage Control on Multimotor Blocks; *O. M. Bundy (Clark Controller Company, Cleveland, Ohio).*

This subject will be considered particularly with respect to the complete electric system because only such a discussion can present an over-all performance picture. The multimotor wire block, to which this discussion applies, is distinguished from previous types by the fact that every attempt has been made to keep slippage to an absolute minimum and not require a large storage of wire on the capstan. Each of the capstans is driven individually by a d-c adjustable-speed motor. Slip is avoided by having each follow motor in the train by a dancer roll rheostat which is operated by a tension arm between the capstans. The problems presented in controlling a drive of this kind include the individual problem of synchronizing and stabilizing each capstan, and the collective problem of accelerating, decelerating, and fast stopping.

Two different sets of conditions control the choice between constant potential variable or voltage power supply at the present time. One of these is the type of power available and the other is the operating characteristics required of the machine. More exacting wire drawing requirements, increased operating speeds, and wider diversity have been major factors in the development and increased usage of the variable voltage control system. Where two or all three of the foregoing factors are of major importance, the variable voltage control system has much to offer.

One of the most important operating improvements which has been found using this system is the better acceleration and deceleration available with a comparable

amount of equipment. This is particularly important on high-speed machines. This has been obtained by careful design of both the control and the generator field circuit. The main point of interest with this particular system is the fact that instead of dynamic braking from the top speed, a regenerative breaking system is used down to the low speed, where dynamic braking is used to make the final stop. With such a system as this the generator and the control system should supply a smoothly rising voltage for acceleration and the reverse for regenerative breaking. This system is modified quite extensively at times to take care of particular problems on certain machines.

The motor itself with its attendant dancer roll rheostat must do the job of synchronizing and stabilizing itself. The rest of the system must handle the motors collectively, so that it is within the range of the motor and its rheostat to stay stable while the machine is being accelerated, operated, and stopped. The contactor scheme of generator field acceleration is used. This system has given excellent operating results. In the power circuit all of the motors are tied together permanently to operate as a unit for acceleration, regenerative breaking, and dynamic braking. The series fields of the motors are in the circuit during the accelerating and running conditions and are cut out of the circuit during the stopping cycle.

When the variable voltage system first was applied to a drive of this kind, where a four to one field range motor had been used previously, the speed range by motor field was reduced to that required only for the different sizes of finish blocks. the drafting range, and that needed for stability and field forcing. By raising the base speed of the motors, or by overvoltage on the motors, providing they were designed for this, it was found that in practically all cases the same motors could be run with much more stability at high speed due to operating at stronger field conditions The loss of speed range by field control of course was made up by varying the voltage and the fact that the voltage can be set at any reasonable value desired gives the machine with this system quite a wide diversity factor.

There is no question but what the economic speeds for various types of wire is going to be raised gradually by a combination of the improvements which are being made in metal, drawing practice, lubricants, and machinery. The last few years definitely have shown that the variable voltage system on this type of block has its place and that its place will be larger as economic speeds are raised.

Electric Equipment for Wire Winders; *H. R. Lloyd* (*General Electric Company, Schenectady, N. Y.*).

Six types of wire winding and unwinding applications of electric equipment include

1. Winding reels that follow separate machines.
2. Winding reels that pull wire through process.
3. Rewinding from coil to reel.
4. Unwinding reels.
5. Rewinding from reel to reel.
6. Rewinding from reel to reel with intermediate capstan.

An electric-reel drive must provide a speed torque characteristic to approach the requirements of the system. The speed torque requirements of the reel will include various components; such as a constant horsepower component for maintaining constant tension during buildup of the reel, and possibly variable or constant torque components for friction, wire bending, traverse mechanism, and the like. Often the reel drive must be suitable for a wire speed range and a tension range. It might be required to provide tension under stalled conditions and to supply extra power for forcing during accelerating and decelerating conditions.

Three fundamental systems for application 1 are a-c and d-c torque motor systems, constant current systems, and mechanical signal systems.

An example of an a-c torque motor system is one that utilizes a wound-rotor motor with sufficient secondary resistance to give a straight-line speed-torque characteristic. Adjustable primary voltage then will provide a family of curves to approach various speed-torque requirements for reeling. An example of a d-c torque motor drive is one that uses a d-c series motor to obtain speed torque characteristics that closely approach constant horsepower.

Constant current systems are illustrated by electronic-motor controls operating against a current limit. For a given wire speed the armature voltage is held constant and the current limit circuit adjusts the motor field to hold the current constant. This provides constant-horsepower speed-torque characteristics.

Where wider tension ranges or smaller tensions than can be held by the other systems are required, mechanical signal means such as dancer rolls, rider rolls, auxiliary capstans, often must be used with the electric drives. With the dancer roll system, the most accurate tension control can be obtained because it is a positive method of measuring tension. There are many modifications of these mechanical signal systems.

The major portion of wire winding applications can be handled by the basic methods discussed in this paper, or modifications of them. To select the proper one for a particular application, requires balancing the operating requirements of the job against the economics of the situation. The important caution that must be exercised when applying a constant horsepower drive is to make sure that the usual constant horsepower requirement for maintaining tension during buildup is not overshadowed by constant-torque auxiliary components.

Flexibility in Multimotor Multispindle Tandem Wire Block Control; *D. E. Donaldson* (*The Electric Controller and Manufacturing Company, Cleveland, Ohio*).

A common type of wire-drawing machine is the multispindle nonslip continuous wire mill in which individual motors are used to drive the several spindles. In this paper it is proposed to discuss two specific applications which illustrate the high degree of flexibility that can be obtained with such a machine, using d-c shunt motors.

In the first application, "interchangeable single and tandem block operation," the user has several blocks which he wishes to operate independently under certain conditions, all in tandem under other conditions, or in any other combination of single and tandem groupings. For independent operation, a complete set of control apparatus is required for each motor. Then additional apparatus is required for switching from independent to tandem operation. Economically a constant voltage power system is called for.

A 4-block machine may have five basic operating combinations:

1. Four independent blocks.
2. One independent block, three blocks in tandem.
3. Two sets of two blocks in tandem.
4. Four blocks in tandem.
5. Two independent blocks, two blocks in tandem.

Transfer of the controllers from one combination to another is accomplished by a manual selector switch.

In any tandem group, the last motor sets the pace and the preceding motors must follow along. Motor speeds are co-ordinated by tension-responsive dancer arms which are located between spindles and control the shunt field rheostats. However, during acceleration when each armature is in series with a separate resistor, the variations in *I-R* drop across the resistors and series fields have enough effect on armature voltages to cause wire breakage. This difficulty is eliminated by providing an electric tie between motor armatures.

Finished wire leaving the last die may be coiled on the last capstan, but to handle greater quantities of wire with fewer stops, a separate spooler is used. The speed of the spooler must be matched with that of the blocks by a dancer-arm in the wire loop between the last spindle and the spooler. Because a full spool represents a heavy inertial load on the spooler, as compared with the frictional load on the spindles, extraordinary measures may be required to get the full spool started and stopped as quickly as the spindle motors. In one such machine, the nine spindle motors operate in a variable voltage d-c system, and the spooler receives power from a separate motor-generator set.

Three independent devices control the spooler speed. First, the spooler motor field is regulated by the dancer rheostat. Second, the spooler generator field is regulated by a tachometer generator mechanically driven by the last spindle motor. Third, the spooler generator has an additional field winding connected to boost or buck the normal field, this action being controlled from a second faceplate on the dancer rheostat.

For stopping the spooler, two independent devices are used. First, a dynamic braking circuit is established across the armature, with shunt field strength still under control of the dancer rheostat. Second, excitation is applied to an eddy-current brake on the spool shaft, under control of the dancer rheostat which has a third faceplate for this purpose.

Constant Potential or Variable Voltage for Wire Blocks; *R. A. Gender* (*Reliance Electric and Engineering Company, Cleveland, Ohio*).

The tone of the electrical papers on the subject of wire blocks seems to imply a debate between the use of constant-voltage d-c power and variable-voltage d-c power. Inasmuch as both are being used successfully in the ferrous and nonferrous industries, we should view the situation in the light of the present-day facts. The facts look like this:

1. Constant-voltage d-c adjustable-speed motors have been in use successfully on single motor and multimotor wire blocks since the early 1920's.
2. Some existing industrial plants have an abundance of d-c constant-potential power.

3. In large and small industrial plants the extension of power or increase in power facilities is overwhelmingly in alternating current and not constant-potential direct current.

4. Variable-voltage power combined with d-c adjustable-speed motors has been in use successfully on single motor and multimotor wire blocks since the middle 1930's.

5. Variable-voltage d-c power is used in increasing amounts in all industries.

6. Variable-voltage power is the natural solution for processing or finishing machines which require several individual motors to stay in synchronism with each other during acceleration, normal running, and deceleration.

7. Each year the machinery designers are producing wire blocks for higher finishing speeds.

8. Increased speed and increased production inevitably requires increased horsepower.

9. Increased delivery or finishing speeds automatically demand a wider speed range because of the necessity of maintaining the same safe "threading" speed and because of economical production of a wide range of products.

10. No increase in machinery torque is required to make the same product at higher speeds if we can neglect gear friction and windage.

Facts 1, 2, and 3 deal directly with the use of constant-potential d-c power. New plants are not extending their direct current—they are conserving it for operations such as cranes. The mere fact that a plant has an abundance of direct current does not of itself support the argument that variable voltage cannot be afforded. Such a view embraces one or two lines of thought; first, the plant is doomed to stagnation without any growth to use that extra direct current or second, the error that resulted in the present oversupply allows a further error in devaluating it. Either point of view is certainly not basically sound or progressive.

Facts 4, 5, and 6 are the obvious ones promoting the use of variable voltage. Any plant with a-c distribution could convert to direct current for adjustable speed drives by using "spot conversion" units to produce variable voltage power from a-c power at the machine where needed.

Fact 5 reflects the trends everywhere and particularly in the metal industries where tremendous advances have been made toward increased production by increased speed. Hot rolling mills, cold reducing mills, bar mills, tube mills, and so on down the line all are using variable voltage to the fullest extent.

Fact 6 takes on a real meaning in modern high speed machinery. We must be able to start and stop safely regardless of the speed to which we ultimately are going. Moreover, high speed is useless if we cannot consistently accelerate to it and decelerate from it. Therefore, a wider and wider speed range is required in order to use the higher and higher speeds of machinery. In many instances, this requires speed ranges beyond the scope of the conventional adjustable speed d-c motor—one good solution is variable voltage.

Multimotor wire blocks fall into the class covered by fact 6. The motors must respond to a control device to keep them in synchronism with each other. Their ability to respond to the control demand put upon them is the net result of their inherent sensitivity and the rate at which the control device demands action. As the speed range of an adjustable-speed d-c motor is increased, its inherent sensitivity is decreased. Moreover, if its speed range were increased to run the machine at a higher speed then the synchronizing control device demand also will be at an increased rate. The wide speed range adjustable-speed d-c constant-potential motor may not be able to meet these requirements. This subject is a "paper" by itself but it will suffice to point out here that motor design facts plus variable voltage control can meet the requirements.

Facts 7, 8, 9, and 10 directly affect and are affected by the machinery manufacturer. These manufacturers courageously have pushed their machines to higher and higher speeds with greater and greater production and lower and lower costs. The machine design is usually not materially different when its speed is increased if the same product is being made. Lubrication and balance may need attention but the strength of the machine from a torque standpoint is unchanged. Therefore, physically, the machine is unchanged and preferably would use the same motor frame size but with a higher horsepower for the increased speed and wider speed range to accommodate the same safe threading speed as well as the new higher production speed. An adjustable speed constant potential motor having more horsepower and more speed range definitely will be a larger and more expensive motor. If, on the other hand, the increased speed range and increased horsepower are obtained through a combination of adjustable speed motor and variable voltage control, then we might retain the original motor frame size and cost.

The solid line in Figure 4 is the curve of a conventional constant potential adjustable speed motor of a given frame size. The dotted line represents a duplicate frame size motor with a greater speed range by variable voltage above and below the original and also greater horsepower in the speed range above the original. It is assumed that the motor frame size in question can operate satisfactorily at the higher rpm. The shaded area represents the gain in speed of machine, the gain in horsepower required, and the gain in production to be expected. All this is accomplished by the proper use of variable voltage without a change in the basic motor frame and cost.

Application of Eddy Current Coupling to Wind Tunnel Drive; *F. W. Sama (Pratt and Whitney Aircraft Company, East Hartford, Conn.).*

The wind tunnel at the United Aircraft Corporation, East Hartford, Conn., is the largest closed-circuit-type tunnel ever constructed of reinforced concrete; it is capable of testing full scale power plant installations as large as 6,000 horsepower at air speeds of 200 miles per hour; it can test engines equipped with propellers as large as 17 feet in diameter; and air speeds of 600 miles per hour can be developed for testing reduced scale models of aircraft. The cross-sectional area of the tunnel at its largest part is 1,200 square feet, while its total length is 630 feet. The fan contained in the tunnel is made up of 20 blades, of the variable pitch type, with an over-all diameter of 26 feet. The fan is driven by a 7,000-horsepower synchronous motor, rated 11,000 volts, 514 rpm.

To vary the speed of the fan, which is a necessary requisite in tests that are conducted at different air speeds, an eddy current coupling is located between the synchronous motor and the fan, rated 6,550 horsepower at 492 rpm. This combination of drive motor and eddy current coupling almost could be termed a "variable speed, a-c motor," for the coupling permits the fan to rotate at any desired speed up to 492 rpm, while the motor drive, of course, is a constant speed source of 514 rpm.

In brief, the eddy current coupling consists of three units:

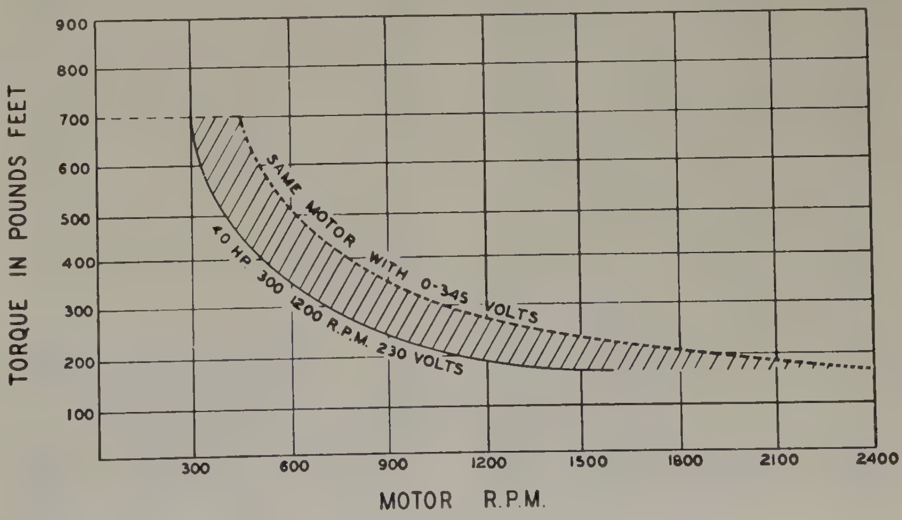
1. The driving member also known as the armature which is held on the shaft of the 7,000-horsepower motor.

2. The driven member which is supported by the shaft of the unit being driven (in this case the wind tunnel fan).

3. The air gap between the driving and driven members, through which the field coils which are mounted in the driven member are excited.

To operate the coupling requires excitation of the field coils, and the amount of excitation depends on the load to be applied and the speed desired. To supply this excitation, a motor-generator amplifier system is used, which consists of a 40-horsepower a-c motor driving a 25-kw d-c generator and a small 3.5-kw d-c pilot generator, the three units having a common shaft. The pilot generator furnishes the field supply to the large d-c generator but to achieve rapid response to load changes and fan speed requirements, an electronic control system is used to supply the pilot generator field. The pilot generator

Figure 4. Curves showing how increased speed range and horsepower were obtained by applying variable voltage with overvoltage to a given motor rating



itself is made up of two windings connected in opposition to each other so that with excitation on one, the voltage is built up, while excitation on the other winding decreases the voltage output of this generator.

For governing the speed, a small alnico-type generator is used, this being mounted on the output shaft of the coupling. Thus, any predetermined speed can be maintained by the co-ordination of the governor generator output with the pilot generator field through the electronic control system. This electronic control system is made up of a rectifier and filter unit into which is fed the ouput voltage of the alnico generator, a reference voltage divider, an amplifier, and a final rectifier system.

For proper operation of this electronic system there is required a direct voltage whose magnitude is proportional to the speed of the output shaft, in this case the fan shaft. This is the voltage supplied by the governor generator, which is fed into the rectifier-filter combination. This voltage then is connected in series opposition to the standard reference voltage and the resultant of the two voltages then is fed to the grid of the amplifier tube. When the fan shaft is rotating at the desired speed the resultant voltage to the amplifier grid is zero. If the fan shaft is rotating faster or slower than the desired speed then the plate of the amplifier feeds excitation to the coupling field coils in such manner as to restore the desired fan speed, that is, if the speed drops below the preset figure, excitation increases; if speed increases field current decreases.

It is desired to mention here that when the 7,000-horsepower motor is not being used for wind tunnel testing, it is put on the line and allowed to "coast," thus using it as a synchronous condenser for power factor improvement. With respect to the rest of the plant, it is in an ideal location, for the wind tunnel is located remote from the main plant and electrically is on the end of the power system. In this manner the power factor of the electric system can be kept at a rather high level, in the order of 90 or 92 per cent.

A Quick Look at the Heat Pump; *Charles A. Williams, E. Haviland Walton (United Illuminating Company, New Haven, Conn.).*

The reason electrical engineers are interested in the heat pump is that this new use for electricity promises to expand the scope of electrical engineering, to create more work and jobs, and to increase the use of electricity in private residences. The heat pump is simply a refrigeration unit (electric motor, compressor, condenser, and evaporator) operated to make use of heat instead of cold. Operated as a heat pump, the unit takes heat out of well water, or the earth, or even the outside air, steps up the temperature through its unique powers of transformation, and feeds warm air or warm water to the circulation system of the house. A steady ample source of heat is needed, such as quantities of outside air, a flow of well water or a river, or water circulated through pipes buried in the earth.

Not only can the heat pump transform heat from a lower to a higher temperature, but it also can transfer about three to four times as much heat energy as it uses up in electric energy. It is this ability to deliver four times as much as it consumes that makes its use economical for heating homes electrically, provided a satisfactory heat source is at hand.

The performance ratio of heat energy delivered by the heat pump to energy consumed is called the "coefficient of performance." In terms of heat, it is

$$C.O.P. = \frac{\text{electric energy supplied} + \text{energy drawn out of the heat source}}{\text{electric energy supplied}}$$

The value of *C.O.P.* depends partly upon the temperature level of the heat delivered to the building by the condenser; the higher that temperature, the poorer the performance. It also depends upon the temperature level of the heat source which supplies heat to the evaporator. The lower that temperature, the poorer the performance.

In this climate (Connecticut) it is not desirable to use air as a source of heat for the heat pump. When the greatest amount of heat is needed in the house the outside air is at its coldest, thus the *C.O.P.* is at its lowest value. Furthermore, when temperatures of 32 degrees or less prevail, the evaporator would collect a coating of frost which would slow down the transfer of heat. These difficulties can be overcome but the cost would be high.

A heat pump using well water as a source of heat is practicable as proved by many installations including that in The United Illuminating Company's building in New Haven. Table I shows the amount of electricity used for heating and cooling in each month of 1947. By way of comparison, we have included the amount of electricity used for lighting the building and it is evident that the amount for lighting exceeds that used for both heating and cooling. Of course the lighting system, although much of it is fluorescent, produces considerable heat. This is useful heat in the winter, but in the summer it must be taken out by the cooling system.

Table I. Electricity Used for Heating, Cooling, and Lighting

1947	Kilowatt-hours Used for Heating	Used for Cooling	Used for Lighting
January	79,100		78,000
February	84,200		70,900
March	73,700		79,100
April	41,400		75,200
May	8,400	12,600	74,500
June		24,000	71,600
July		35,900	74,000
August		34,600	71,900
September		21,900	70,900
October	3,828	15,950	79,000
November	49,400		71,900
December	86,400		80,700
	426,428	144,950	897,700

Taking electricity at $0.02 per kilowatt-hour, operating costs in 1947 were about as follows:

	Heating	Cooling	Total
Electricity	$ 8,528	$2,900	$11,428
Operating labor	6,000	3,100	9,100
Maintenance	750	250	1,000
	$15,278	$6,250	$21,528

Some Aspects of Heat Absorption by a Ground Coil; *Charles H. Coogan, Jr. (University of Connecticut, Storrs, Conn.).*

In New England the most promising heat source for the residential heat pump is the heat stored within the crust of the earth. Some of this heat can be absorbed by burying a series of copper tubes in the earth and then circulating a fluid, such as a refrigerant, through these tubes.

A research and development project sponsored by the Connecticut Light and Power Company is currently in progress at the University of Connecticut having as primary objectives the determination of a rational basis of ground coil design and also heat transfer data for the direct expansion ground coil. When the temperature gradients in the undisturbed earth are small the buried absorber can be analyzed mathematically as a line sink similar in many ways to the buried electric cable which customarily is treated as a line source.

During the summer of 1947 the heat pump unit was operated continuously for about 14 days. Measured heat absorption rates at the end of this time of 46.9 Btu per hour per foot of length of 3/4-inch coil, buried at an average depth of 5.68 feet and operated with Freon 12 using direct expansion in the ground with an evaporator temperature of 34.3 degrees Fahrenheit, check rather well the rate of 49.6 Btu per hour per foot of length predicted by the line sink theory when the soil has a thermal conductivity of 1.5 Btu per hour per foot per degree Fahrenheit.

During certain months in the year the line sink theory should be particularly well adaptable to this problem, as for example, April when the temperature gradient in the earth is very small. A more detailed and accurate analysis can be made by superimposing the temperature gradients of the earth on the line sink analysis.

Mobile Telephone Service—General Considerations; *L. B. Grew (Southern New England Telephone Company, New Haven, Conn.).*

This paper describes the development within the telephone industry of mobile telephone service in the 30–44 and 152–162 megacycle bands. Urban service is designed for contacting vehicles within a fixed metropolitan area and the 152–162 megacycle band is used. Highway service is provided for main line trunk highways and operates in the 30–44 megacycle band.

Calls may be passed from wire telephone to vehicle, vehicle to wire telephone, and vehicle to vehicle. A selective signaling device permits calling any particular unit as each vehicle is assigned a specific telephone number. The alternate uses of the one antenna on the vehicle for transmitting and receiving have necessitated the incorporation of a push-to-talk button in the mobile equipment which switches the antenna from receiver to transmitter.

Mobile Telephone Service—Technical Aspects; *James M. Henry (New England Telephone and Telegraph Company, Boston, Mass.).*

Propagation of very high frequencies over the earth's surface is characterized by a limited range in miles. In general 40 megacycle signals are useful within distances of 40 to 60 miles and 150 megacycles signals within

30 to 50 miles. Local terrain conditions exert a considerable influence on the ranges. Hills or obstructions cast "shadows" which introduce a penalty. The locations of radio transmitters and receivers can be so chosen that transmission will be adequate from points of observed minima.

The effective height of antennas for either transmitters or receivers is a powerful factor in determination of range. The greater this height with reference to the immediate vicinity, the more effective the antenna. Antenna performance also is affected profoundly by the slope of the earth beneath. In general, steep slopes dropping away from antennas are the most desirable for increasing the range. Level or gently sloping earth, even at a great elevation, may nullify the gain to be expected from its alittude.

Charts have been made which permit reasonably accurate predictions of performance of a radio system from topographical data. These charts include the following parameters: effective antenna height, field strength in terms of decibels of power received below one watt, distance in miles and degree of noise at the receiver for the frequencies under discussion. Charts also show the loss in decibels which may be expected from obstructions having a known height, slope and extent.

The noise to which receivers are exposed that is generally most troublesome is that caused by man's machinery. Of this, the automobile is the most generally consistent offender and consequently receivers should be located where there is a minimum of motor traffic in the vicinity, if maximum range is to be realized. Other sources of noise, of course, exist and should be avoided where possible.

Interference to one radio system by operations of another, impose considerations of location of stations and frequency assignments. The progress of the art at present does not permit interference free operation in the same general area on assignments adjacent to each other. Spurious frequencies may be developed in transmitters and receivers which are quite different from the original signals which produce them. Some of these may be diminished by proper adjustment of the apparatus, while others can be eliminated only by special treatment of their circuits. Increasing the separations of transmitters, or of receivers and transmitters, may be required. Oftentimes it is necessary to seek different frequency assignments.

Considerations in connecting radio circuits to the wire telephone network include automatic regulation of speech volumes, provision for switching, supervision and testing, and selective signaling to call the desired vehicle to the exclusion of all others. These features generally are not required in systems transmitting information from a central point only.

Mobile Telephone Service—Private Systems; *D. S. Dewire (New York Telephone Company, Albany, N. Y.).*

Radio has been adopted by the telephone companies to extend private contract telephone service to moving vehicles. Law enforcement agencies were the first to use radio for communication with vehicles, using amplitude modulation at about two megacycles for 1-way land-to-car transmissions. When frequency modulation equipment became available at higher frequencies, practical car transmitters were possible and were used to supplement the amplitude modulation systems. New systems are all 2-way frequency modulation, usually about 155 megacycles.

The simplest frequency modulation system includes a desk console with low power transmitter, receiver, and loud-speaker, and a microphone and handset with a coaxial antenna for the land station and a transmitter-receiver under a single housing with control head, loud-speaker, microphone or handset, and whip antenna at the car. Such a system will serve the average small city. Optional arrangements for land stations include higher power transmitters, remote receivers, and, if required, transmitters to utilize more efficient locations, multiple control positions, and selective signaling. For mobile units, higher power transmitters may be used with transmitter and receiver in separate housings.

For its contract systems, the telephone company owns, installs, and maintains all radio equipment. Licensing is cared for by the customer, who also provides space and power for the equipment.

More complex systems can be engineered specially to meet specific requirements. The Albany, N. Y., municipal police have a system with one low power land station and 30 mobile units to cover an area of about 25 square miles. Seven precincts and three officials have access to the radio system in addition to and under control of a chief dispatcher. All communications are heard by loud-speaker at all points. Wire lines from all points concentrate in a telephone central office, which provides amplification and control arrangements. Equipment in precincts and officials' offices consists of handset and loud-speaker. The dispatcher has a radio console and a control key box.

The Pennsylvania state police have a radio system consisting of radio transmitters and receivers at or near all police stations. Wire lines are used between some police stations and nearby radio locations. Dual frequency operation at about 40 megacycles is used, with one receiver on each frequency at each station. One of these receivers can be muted when required.

The New York state police have a radio system consisting of radio transmitters and receivers on hilltops throughout the state connected by wire lines to police stations in such a manner that any police station in a particular zone has access to all transmitters and receivers in the zone. Higher echelons may monitor or use any zone radio equipment at will. The wire network may be used for intercommunication without radio. Dual frequency radio operation is used at about 42 megacycles.

These systems were engineered and provided by the telephone company. Similar systems can and are being providedfor organizations, where it is an advantage to be able to operate such a system with-out having to own, install, and maintain the equipment.

Microwave Radio Facilities of the Bell System; *J. Harold Moore (American Telephone and Telegraph Company, New York, N. Y.).*

For a number of years Bell Telephone Laboratories has carried on a program of research and development to determine how radio relay might be used to advantage in the nationwide communication network. This program being well along when interrupted by the war, it was decided at the close of the war to proceed with a full-scale field trial of a broadband radio relay system. Taking into account various factors, the 4,000-megacycle region was chosen. The route selected was one between New York, N. Y., and Boston, Mass., with seven intermediate relay stations.

During the 2-year period following the war, while work was under way on the New York–Boston project, steps were taken by Bell System operating companies to gain early experience with microwave equipment. An 8-channel radiotelephone system developed during the war, and a newly developed microwave system intended primarily for short haul television transmission were employed; both utilize highly directional antennas.

The 8-channel system bears the military designation *AN/TRC6*, employs pulse position modulation, and has a peak power output of a few watts at about 4,500 megacycles. Equipment of this type was placed in regular message telephone service around the middle of 1946 by the New England Telephone and Telegraph Company between Barnstable, Mass., and Nantucket Island, Mass., and by the Pacific Telephone and Telegraph Company between Los Angeles, Calif., and Catalina Island, Calif.

The frequency-modulated television link of simplified design has a power output level of a few tenths of a watt in the 4,000-megacycle region. Examples of its use for video transmission include a 2-section layout from West Point, N. Y., to New York, N. Y., provided bythe New York Telephone Company, and a 3-section layout from Baltimore, Md., to Washington, D. C., provided by the Chesapeake and Potomac Telephone Companies.

Late in 1947 the New York-Boston project was completed. Two 2-way broad-band communication channels are provided, each capable of transmitting a band of signal frequencies of 30 cycles to 4.5 megacycles. Operating in the 4,000-megacycle region, each repeater provides a maximum gain of some 80 decibels, shifts the frequency of the outgoing signal by 40 megacycles, and transmits about one watt of power. The antennas consist of pyramidal horns with metal plate lenses for focusing, providing a gain of nearly 40 decibels over a nondirectional radiator. Low index frequency modulation is employed at present; however the repeaters will accommodate other forms of modulation.

In connection with the opening of this system for experimental service on November 13, 1947, provision was made for viewing a television test pattern at New York before and after making two round trips to Boston. It was difficult to detect any impairment in the test pattern after transmission through this 880-mile system. Since that time the system has been used for more than 40 television program periods, with good results.

Measurements indicate that at least 240 speech channels can be handled on two oppositely directed broad-band channels. The system also has been arranged to handle a group of 20 message trunks, pending installation of additional terminal equipment.

The next large radio relay project will extend from New York to Chicago; this is scheduled for completion in about two years. Other active projects include the Chicago-Milwaukee and Toledo-Detroit systems, scheduled for completion later this year. Up to the present time, the experience of the Bell System with radio relay is encouraging.

Papers Digested for Rubber and Plastics Conference

These are authors' digests of the papers presented at the AIEE conference on electrical engineering problems in the rubber and plastics industries which was held in Akron, Ohio, April 20, 1948. Full texts of all the papers and discussions are being published in the "Proceedings of the Conference on Rubber and Plastics Industries" which will be available soon at $3 per copy ($1.50 to AIEE members). Orders for this publication should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

Electric Power Distribution for Small Rubber and Plastic Plants; *H. J. Finison (General Electric Company, Schenectady, N. Y.), B. D. Morgan (Johnson and Johnson Company, New Brunswick, N. J.), R. S. Ferguson (Goodyear Tire and Rubber Company, Akron, Ohio).*

In order to study the problems presented in laying out electric power distribution systems for small rubber and plastic plants, it was necessary to choose some common denominator and to pick a top limit as to the size of a "small" plant. It was found that in plants where only one Banbury or other mixing machine and one calender train were required, the electrical distribution problems were almost identical. This seemed to be true regardless of the size of Banbury and calender train required. In any of these small plants the main electrical problem is the supply of power to the heavy processing equipment such as Banburys, mills, extruders, and calenders. The greatest apparent difference in the plants studied was in the finishing operation. Although these finishing operations covered a wide variety of machinery, operations, and space required, the power required was so minor that it had no effect on the type of distribution system used.

In studying the problem of the selection of the proper voltage for the operation of the heavy processing equipment, it was found that in all instances a 440-volt distribution system was the most economical. However, because of convenience and ease of expansion, a 2,300-volt system was recommended as being most desirable. One of the major items to be considered in selecting a power distribution system is the ease of obtaining replacement equipment in case of a breakdown. It was for this reason that 2,300 volts was recommended over 4,160 volts in spite of the increased flexibility of the 4,160-volt system.

To make a complete study, a proposed Johnson and Johnson Company adhesive plaster plant was laid out in detail. With the power rates available at the Johnson and Johnson site, it was found advisable to purchase power at 33,000 volts. This, of course, required the use of an outdoor transformer station where the voltage was reduced directly to 2,300 volts. This particular solution could not be applied to all plants because of the variation in the distances involved and the supply of voltages available. However, in general, it was concluded that an attempt should be made either to purchase at or transform to 2,300 volts upon entering the building.

The voltage dip caused by starting these large processing equipment motors also was given serious consideration. This problem is naturally prominent in a small rubber plant with a correspondingly small power supply transformer. However, it was interesting to note that the additional cost of a wound rotor motor plus control which amounts to approximately $4,000 in the Johnson and Johnson case could be used to buy an additional 1,000 kva of transformer capacity which would reduce the voltage dip almost half. This additional transformer capacity also would be advantaegous in the starting of other motors in the plant and in future plant expansion.

The general conclusion was that in laying out a new plant it would be helpful to look at the case history of The Johnson and Johnson Company, but that local power conditions would have some effect on the selection of the most desirable system.

Separate Electric Equipment Rooms Versus NEMA Enclosures for Protection of Motors and Controls; *F. A. Green (B. F. Goodrich Company, Akron, Ohio).*

In common with other process industries, electric equipment used in the manufacture of rubber and plastic products is subject to many injurious influences such as corrosive atmosphere, abrasive and conductive dusts, plus an abundance of dirt that imbeds itself in every crevice and clings tenaciously to every surface. Hazardous atmospheres are common and inflammable materials are ever present.

Enclosures for motors and controls, resistant to most of the deteriorating influences, are available. It is usually impractical to locate all electric equipment in separate rooms. It also may be uneconomical to provide in all cases the special enclosures required to meet the various conditions in production areas.

Of the 17 types of motor enclosures there appears to be a growing preference for the totally enclosed type, particularly in the general purpose sizes. Experience has shown that larger motors as used on mills and Banburys require considerably less maintenance when located in a room separate from the production area. Unfortunately production layouts seldom lend themselves to the employment of this scheme.

If provision is made in the original plant design, motor generator sets, motor controls in the floor mounted sizes, transformers of the dry and askarel types, and distribution switchgear may be located conveniently in equipment rooms. Where hazardous atmospheres exist in production area, small controls also may be economically included in the equipment room.

Advantages of equipment rooms include a number of important items. Safety of both life and property is increased and service reliability improved where electric equipment is accessible to only qualified personnel, removed from vicinity of inflammable material, trucking, steam and water lines, and subject to the controlled conditions of a separate room. With the production area free of large electric apparatus, arrangement of process equipment is simplified, stock handling is facilitated, storage space is increased, and labor costs are reduced. Control enclosures may be eliminated in many instances with an appreciable reduction in cost.

Equipment rooms also have disadvantages. Separate rooms for electric equipment require ventilation for heat removal and to create slight pressure to exclude contaminated air. Additional conduit work may be necessary also. The cost of these items must be weighed against the extra cost of maintenance in production area. In addition to the extra cost for special enclosures, conscientious maintenance is required if service expectations are to be realized. Door gaskets must be kept in place, bolts and wing nuts kept tight, and on the oil immersed types of control the oil must be replaced periodically and oil level watched.

With regard to motor applications it can be said that

1. Totally enclosed motors should be considered for all general purpose applications.
2. Location of large motors in "equipment rooms" permits the use of least expensive motors and results in minimum maintenance.
3. Separate ventilation should be considered for large motors in production area.
4. Large slow speed motors, 100–150 rpm, tolerate dirty conditions better than higher speed types.

As far as control applications are concerned, it can be stated that

1. On the basis of cost and maintenance, controls for hazardous processes should be located in a separate room.
2. Special control enclosures have the disadvantage of being expensive and impose additional burden on maintenance.
3. "Equipment rooms" have disadvantage of requiring ventilation equipment and more conduit work.
4. The advantages of controls in separate rooms include improved production conditions, less chance of accidental damage, less expensive controls, reduction of maintenance cost, greater reliability, and reduction of hazards to life and property.

The manufacturers should be commended for their ingenuity and diligence in developing the numerous types of special control enclosures. Instances always will occur where they are desirable. However, in the opinion of the author, the "equipment room" is a definite requirement of plants of the rubber and plastics industry.

Spot Conversion Adjustable Speed Drives in Rubber and Plastics Manufacturing Plants; *C. E. Robinson (Reliance Electric and Engineering Company, Cleveland, Ohio).*

Adjustable-speed drives in the rubber and plastics industries are a means for increasing production without increasing costs or decreasing quality. The spot conversion drive, defined as a device for securing from an a-c distribution system all of the advantages inherent in motors operated on adjustable voltage direct current, is divided into three types:

1. The conventional rotating and control equipment.

2. The electronic conversion unit.

3. The rotating equipment, electronically excited and controlled.

In rubber and plastics mills there is an increasing demand for greater flexibility of operation of the various processing units. Calenders, bias cutters, tubers and tuber conveyer lines, tire building machines, and other processing and handling machines require very flexible driving equipment if their full productive output is to be realized. Not only is it necessary to provide flexibility of operation to secure maximum production, it is also desirable from the standpoint of securing uniformity of quality. Lack of uniformity of quality from one machine not only may affect the finished product but make more difficult the operation of machines which handle subsequent processing of the material.

Even where a-c and d-c power are both available at the point of installation of a machine, a constant-potential d-c motor with necessary control equipment may not be the best drive when subjected to critical economic analysis. For installations up to ten horsepower, spot conversion equipment actually can be purchased more cheaply. In installations above ten horsepower, when the costs of plant d-c generating equipment and plantwide d-c circuits also are taken into consideration, the economic advantage of spot conversion equipment may remain pronounced in even very large horsepower ratings.

The economic case for using spot conversion units is strongest where a new plant is involved because only distribution facilities for a-c power supply at the normal plant voltage of 400 volts are required. From this distribution network all induction motors not requiring flexibility of operation, as well as the spot conversion units of smaller power requirements, can be served. Separate high-voltage feeders provided for the large a-c motors operating such units as Banburys and mill lines and the spot conversion units with power requirements above 100 horsepower actually cost considerably less than did a combined system requiring distribution of both alternating and direct current. Where wide speed ranges are required or where smoothness of acceleration and deceleration as well as other operating characteristics are desired, the spot conversion system provides facility for meeting this requirement where the constant potential d-c system does not.

Refinements in the enclosure of spot conversion drives, which virtually have made these units portable "motor rooms," include simplicity of installation, reduced maintenance, and ease of relocation when machines or processes have to be moved.

The Measurement and Control of Tension and Its Relation to Motor Input; *H. L. Smith (General Electric Company, New York, N. Y.).*

One problem in driving processing trains in the rubber industry is the measurement and control of fabric tension. Large changes in tension can result from shrinkage or stretch in the fabric, eccentricity in the rolls, and so forth. Many methods of controlling tension are used; it may be the weight of the festoon platform or it may be a dancer or tension roll or it may be the armature current in a d-c motor. The last method, which has many advantages, has been used very successfullly, but has the drawback that armature current is not a direct measure of fabric tension, and the accuracy of the control is affected by mechanical losses in the driven unit. In variable voltage multiple unit drives the effect of *IR* drop through the motor is also an important factor. Motors with different *IR* drops do not change their speed proportionately as their armature voltage is changed and their characteristic must be compensated for.

Examination of the fundamental characteristics of the d-c motor, that is, the relation between armature current, flux, and torque; the relation between speed, voltage *IR* drop, and flux, show the effect of *IR* drop and why constant armature current can be used successfully for tension control.

The effect of mechanical losses in the driven unit is to reduce the accuracy. With fixed diameter rolls, if these mechanical losses remain constant they can be compensated for in the current maintained and it is the variation in mechanical losses that are difficult to compensate for. The effect of mechanical losses in wind up, center driven rolls is quite different. Constant horsepower is required to maintain constant tension at any one fabric speed. As the roll builds up in diameter, the torque must increase in proportion. The mechanical losses are constant torque or even may be higher at the empty roll speed than at the full roll speed. The effect of these losses is to make fabric tension too low with an empty roll and too high with the roll full. With the armature current held constant, the larger these mechanical losses are in relation to the power required to provide tension, the more the tension will vary from the required value. The total range of tension which may be used has definite limits depending upon the accuracy required at the lower ranges of tension. This also means that when deciding on the maximum tension requirements, values in excess of those actually required should not be selected, otherwise normal operation may be in the low tension range where mechanical losses are a larger percentage of the tension requirements making it more difficult to maintain tension within the desired limits.

A procedure has been set up for making tests and securing data on power input and speed to calculate tension. Although the assumptions are not strictly accurate because of variation in motor losses they are sufficiently accurate for all practical purposes.

Temperature Measurement and Control on the Electrically-Heated Molding Processes for Rubber and Plastics; *F. L. Spangler (Leeds and Northrup Company, Philadelphia, Pa.).*

Electric resistance heating is used universally for the injection molding of rubber and plastics and is being applied to an increasing extent to extrusion and to compression and transfer molding. In these processes, temperature is the most difficult variable to control and the application of the proper control system offers some of the greatest potential improvements in rates of production and product quality.

All of these processes have common control characteristics. Because the primary element is located in a comparatively large mass of metal between the heat source and the material being molded, these processes have inherent lags which result in a cycling control band when the process is controlled by a 2-position system even if the control system itself contains no response lags. A proportioning control system which is capable of compensating for these process time lags is necessary if close control of temperature is to be maintained.

The effect of temperature on the molding materials also indicates the value of close temperature control. Generally, higher operating temperatures make possible faster molding cycles. Rubber and thermosets have definite time-temperature relationships for successful molding and sizeable deviations from the specified curing temperature appreciably can affect the product quality. The effect is more pronounced at the higher operating temperatures where the period of deviation easily can exceed the curing time. In injection molding the degree of plasticity and the amount of heat carried by the thermoplastic as it enters the mold determines how well the mold is filled. Close temperature control permits operation at the top safe temperature which will not decompose the thermoplastic and thus provides greater rates of production.

The requirements for the temperature control system are

1. Minimum of response lags in primary element, measuring circuit, and control circuit.

2. Reliability and stability obtained through a permanent calibration and permanent sensitivity.

3. Minimum maintenance.

Of the temperature controllers currently in use, the potentiometer and Wheatstone bridge controllers meet these requirements and can be provided with complete proportional control action. A proportioning control system which has been used to a large extent is the duration adjusting type where proportional action is secured by regulating the ratio of the "power on" time to the "power off" time. This ratio is varied not only as a function of temperature change, but as a function of both how far and how long the temperature is off the control point. Heat input is supplied exactly as needed to maintain temperature regardless of changes in load or supply line voltage.

The primary elements most commonly used are thermocouples and resistance thermometers. A thermocouple design which eliminates errors due to thermally produced electric currents consists of small gauge insulated wires mounted in one-eighth to one-fourth-inch diameter tubing with the hot junction brazed into the end of tube. The modern resistance thermometer is a durable primary element which has a better accuracy than standard thermocouples and a speed of response which is equal to that of the smallest miniature pipe type thermocouples.

Electric Braking for Rubber Mills and Calenders; *B. J. Dalton (General Electric Company, Schenectady, N. Y.).*

Quick stopping of rubber mills and calenders as a safety measure is primarily a problem of stopping the driving motor; however, the distance the rolls travel during the braking cycle is dependent on the

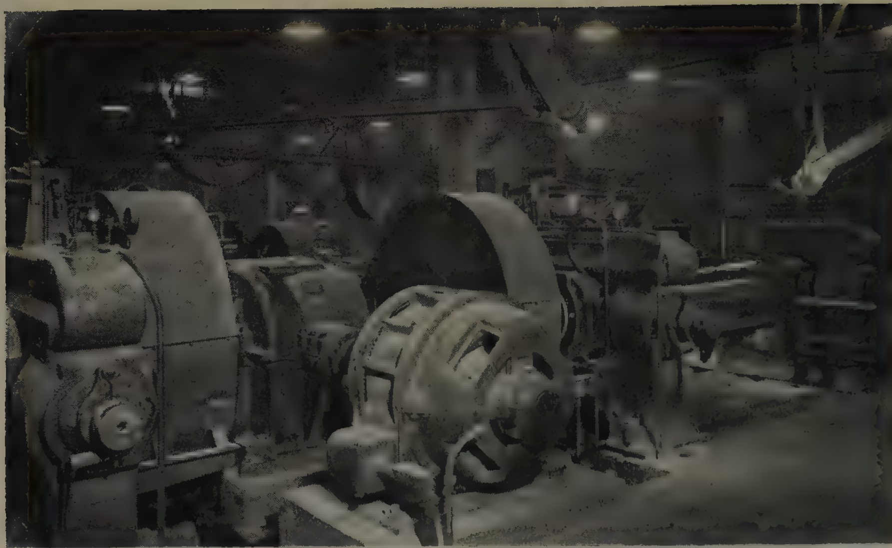


Figure 1. Two rubber mills and common 300-horsepower 720-rpm synchronous driving motor

operating time of the control equipment, as well as the number of revolutions the motor travels after braking power is applied. The operating time of the power contactors in establishing the braking circuit will vary over about a 3-to-1 ratio, depending upon the type of braking circuit and the type and size of contactors employed. The number of revolutions required to stop a motor after braking power is applied is entirely dependent on the ratio between the kinetic energy stored in the motor and the rate at which the energy can be dissipated. These in turn are dependent on the type and rating of the motor and the braking system used.

Synchronous motors are used widely to drive rubber mills and when dynamic braking is used they provide in general the most effective electrical method of stopping these machines. To obtain minimum stopping distance an optimum motor speed of about 600 rpm should be selected as this gives the smallest ratio of stored energy per horsepower. Also, to obtain minimum stopping the optimum value of dynamic braking resistance must be used. Induction motors sometimes are used for driving rubber mills and are stopped by plugging, but in general the stopping performance of these drives is not as favorable as synchronous motor drives.

D-c motors usually are applied for driving calenders and for providing the required wide speed range. Most calender motors are operated as yet from constant potential shop busses and must be stopped by dynamic braking. Speed control by motor field weakening results in the use of motors with high stored energy per horsepower at top speed and therefore makes the motors difficult to stop. Adjustable voltage calender drives have several operating advantages and also provide better stopping performance than constant voltage drives because the amount of motor field control and consequently the stored energy per horsepower is reduced, and also because the armature current can be held more nearly constant throughout the braking period. Regenerative braking offers the greatest improvement over dynamic braking when relatively small amounts of motor field control are used.

Roll travel during stopping of rubber mills and calenders can be calculated with a reasonable degree of accuracy. With the more favorable stopping system the control operating time generally will result in from 20 to 30 per cent of the roll travel, while the motor stopping distance will be from 70 to 80 per cent of the total.

Electric Drive Characteristics for Rubber Machinery; *A. T. Bachelor (Westinghouse Electric Corporation, East Pittsburgh, Pa.)*

The bulk of installed horsepower in the rubber industry is applied to mills, Banbury mixers, plasticators, extruders, and calenders. This paper discusses the requirements of electric drives for these machines and describes some recent developments.

The Banbury mixer is an enclosed batch type mixing machine. A single speed drive is provided by a synchronous or induction motor with 125 per cent starting torque, 250 per cent pull-out torque and, for the synchronous motor, 100 per cent pull-in torque. A 2-speed drive may be obtained by one of several methods of which the 2-speed single-winding synchronous or induction motor is most common. Provision is made for reverse operation for adjustments or to start after a jam.

The plasticator is an internal screw type machine which is usually driven by a synchronous or induction motor of approximately 700 horsepower at 600 or 720 rpm. 250 per cent pull-out torque and about 100 per cent pull-in torque are adequate. 125 to 150 per cent starting torque is needed to permit starting with the machine loaded. Reversing is required to assist in starting a heavy load.

Mills and mill lines require a constant speed drive having 125 per cent starting and 250 per cent pull-out torques, with 100 per cent pull-in torque. A mill is an open machine with exposed rolls and requires emergency stopping to limit the operating hazard. These requirements are met best by the synchronous motor with full voltage, reversing, dynamic braking control.

With regard to motor construction for a-c drives a number of points are of interest. A special field coil construction for synchronous motors was developed to meet conditions caused by use of carbon black in very finely divided form for synthetic rubbers. The more finely divided carbon had caused failure to ground. The new field coil design features thorough ground insulation all around the coil and leads. Motors with these coils have an excellent service record.

Development of the copper fin construction for totally enclosed fan cooled motors has reduced motor size by improving the efficiency of heat transfer. Figure 2 shows the construction of the stator. Cooling is facilitated by copper fins built into the stator core and projecting radially beyond the core. External cooling air supplied by a blower on the motor shaft passes around the circumference of the stator and picks up heat from the fins.

Extruders and tubers require an adjustable speed drive. With constant voltage d-c drives, a four-to-one production speed range obtained by field control is typical. In the case of the 115/230-volt system only two-to-one speed rage by field control is required. The adjustable voltage drive offers a much wider speed range with improved regulation and more flexible control.

Calenders are open roll machines of three or four roll construction, requiring an adjustable speed drive with dynamic or regenerative braking for safety stopping with a minimum of roll travel. Where a single voltage d-c system is available an adjustable speed motor having four- or five-to-one speed range has been used. With a 115/230-volt d-c system the four-to-one speed range is obtained with a motor having only two-to-one field control. The adjustable voltage drive is now well standardized for calenders, using a combination of armature voltage and field control.

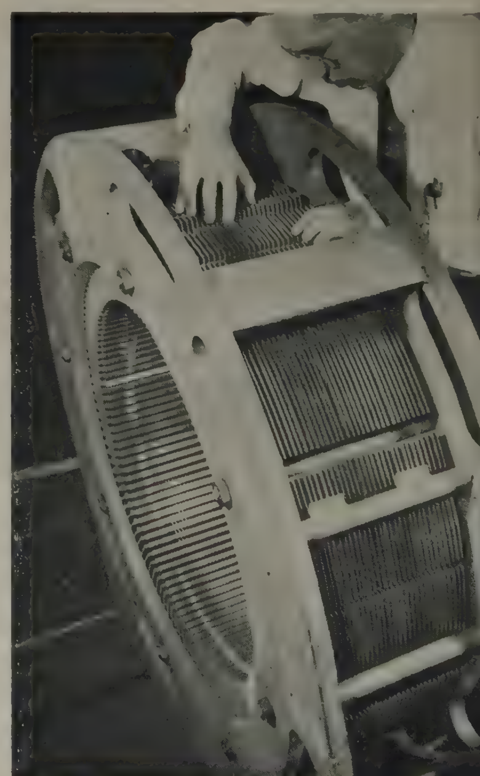


Figure 2. An example of copper fin construction used on a totally enclosed fan-cooled motor

Shown here is the construction of the stator. Copper fins projecting radially from the stator core facilitate cooling

INSTITUTE ACTIVITIES

Our Financial Problem

—*A Message From the President*

The financial chart mailed to members with bills for annual dues could not have been surprising to the overwhelming majority of the membership. It has been no secret that for the past two years the Institute, like many other organizations, has been plagued with inflationary trends. The Institute's monthly income and expense curves crossed late in 1946 and since that time, despite careful expense control, the Institute has been operating at a deficit.

In view of this present situation and the uncertainties of the future, the board of directors felt it their duty to present the facts to the membership. A number of members have made various suggestions and comments, and these are being considered by a special committee appointed to study the entire financial situation.

While this analysis is by no means completed, several facts are already abundantly clear. The financial situation is not acute—yet. During past years the Institute, through wise management, has been able to accumulate a surplus as a cushion against such contingencies. Every economy consistent with a progressive program has been effected to combat rising prices. But danger may be ahead and the officers must bring, in good conscience, this fact to the attention of the membership. There is no way of forecasting the future with any certainty, but present trends, if they continue, cannot bring anything but trouble to the Institute. Your officers believe it would be extremely unsound to continue to whittle away accumulated reserves to meet budget deficits.

To this end, it appears imperative to adopt all possible measures to balance the budget. The Institute already is undertaking measures to hold expenditures to a minimum and to make as many of the Institute's services self-supporting as possible. Emphasis also is being placed on increased income from advertising in *ELECTRICAL ENGINEERING*, both through higher rates and increased volume, and definite results are already apparent.

Even with such measures, however, the financial outlook is not bright. Additional revenue appears to be necessary. To date, no definite plans have been made to raise dues but to say at this time that dues will NOT have to be raised would be rash indeed. The economic future is too uncertain for sound prophecy. Under such circumstances, with rapid changes possible in either direction, it would appear that the utmost flexiblity will be needed in determining the financial policies of the Institute to meet the problems that may lie ahead.

This is not now the case. At present the schedule of dues is a part of the Institute's constitution and thus can be changed only by constitutional amendment. Assuming that such a change were desirable, and that

B. D. Hull, AIEE President 1947–48

the necessary machinery were set in motion at once, the new schedule could not be put into effect for nearly two years—until May 1, 1950, at the earliest. It has been suggested, therefore, that the constitution wisely might be amended to remove the dues schedule therefrom and to place it in the bylaws, thus vesting the board of directors with the responsibility to take such action as they may deem necessary and appropriate to maintain the financial integrity of the Institute. This does *not* mean an immediate or inevitable increase in dues. It *does* mean that the directors would be free to act, quickly and easily, to meet whatever emergencies might arise. As the elected representatives of the membership, the directors are vested with comprehensive responsibilities for the guidance of the Institute. A constitutional amendment to give them the necessary flexibility to deal with the most critical problem the Institute is likely to face in the foreseeable future is simply matching this responsibility with the authority essential to carrying out their tasks effectively.

Further consideration of this problem will appear from time to time in *ELECTRICAL ENGINEERING* so that the membership may be well informed. It is hoped that the membership will feel free to make constructive suggestions for the guidance of the board of directors.

Conference on Electronic Instrumentation in Medicine and Nucleonics Planned

Plans are being made to combine two previously announced AIEE technical conferences, one on electronic aids to medicine (*EE, Feb '48, p 194*) and the other on nucleonic instrumentation (*EE, June '48, p 602*). These two meetings are being combined into a joint 3-day gathering which is to be known as the conference on electronic instrumentation in medicine and nucleonics. It is scheduled to be held in New York, N. Y., November 29 to December 1, 1948.

The AIEE nucleonics committee with Doctor J. J. Smith, General Electric Company, New York, N. Y., as chairman; and the AIEE electronics subcommittee on electronic aids to medicine under the chairmanship of Doctor W. A. Geohegan, of the anatomy department of Cornell Medical College, New York, N. Y.; were the two groups planning the two original conferences. In drawing up their plans they found an area of common interest in their respective subjects and as a result decided to combine their efforts.

As presently conceived, the program is being so arranged that the "area of common interest" falls on the second day of the meeting. Thus the first day will be devoted to electronic aids to medicine covering such items as biological amplifiers and recording devices (cathode-ray oscillograph, electrocardiograph, and electroencephalograph). The second and third days are to cover nucleonic instrumentation including subjects of interest in medicine and physics. The second of these three days is to be devoted to matters of interest to medical personnel including stable isotope measurement. Medical people will be especially interested in the first two days' sessions, and physicists and engineers will find that the second two days' sessions are of particular interest.

The Institute of Radio Engineers will join in sponsoring this conference.

Other agencies which will be invited to co-operate in the program include Brookhaven National Laboratory, Upton, N. Y.; Argonne National Laboratory, Chicago, Ill.; Oak Ridge National Laboratory, Oak Ridge, Tenn.; the National Bureau of Standards, Washington, D. C.; and *Nucleonics* magazine, of the McGraw-Hill Publishing Company, New York, N. Y.

As was done in previous conferences, registration material and final programs will be mailed only to a special mailing list of those definitely interested in the subject. Similarly, it is expected that a "Proceedings of the Conference on Electronic Instrumen-

tation in Medicine and Nucleonics" will be published.

Further information on the conference and registration may be obtained by writing to C. C. Wilson, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

AIEE Board of Directors Meets at Headquarters in New York

A regular meeting of the AIEE board of directors was held at Institute headquarters, New York, N. Y., April 23, 1948.

The minutes of the board of directors meeting of January 29, 1948, were approved.

Approval by the executive committee of proposed "American Standard for Graphical Symbols for Electron Devices" *Z32.10* was reported and the action was approved by the board of directors.

MEMBERSHIP

Executive committee actions on membership applications were reported and approved as follows:

As of February 26, 1948—Ten applicants transferred and one applicant elected to the grade of Fellow; 36 applicants transferred and 35 elected to grade of Member; 189 applicants elected and one applicant reinstated to grade of Associate; 477 Student members enrolled.

As of March 25, 1948—Six applicants transferred to grade of Fellow; 35 applicants transferred and 25 elected to grade of Member; 179 applicants elected to grade of Associate; 811 Student members enrolled.

Recommendations adopted by the board of examiners at meetings on February 19, March 15, and April 15, 1948, were reported and approved. Upon recommendation of the board of examiners, the following actions were taken:

Three applicants were transferred to the grade of Fellow; 36 applicants were transferred and 41 were elected to the grade of Member; 618 applicants were elected to the grade of Associate; 682 Student members were enrolled.

FINANCES

Monthly expenditures from general funds were reported by the finance committee and approved by the directors, as follows: February, \$62,954.74; March, \$57,967.66; April, \$53,339.86.

Upon recommendation of the finance committee, the directors authorized the opening of an Institute account in the Toronto Branch of the Canadian Bank of Commerce, in which will be deposited all funds received from members and others in Canada, and from which payments may be made to members and others in Canada.

A contribution of \$300 for the United States National Committee of the International Commission on Illumination for the present year was voted.

Report was made that the Institute has been notified by counsel that the New York Supreme Court has approved the dissolution of the Italy America Society and has directed that the funds, about \$18,700.51, remaining in the Society's Allessandro Volta Memorial Fund be delivered to AIEE. (The board of directors, in June 1947, accepted the offer of these funds for the establishment of a Volta fellowship or prize, and referred to the committee on planning and co-ordination the development of a plan of procedure. The committee has not reported as yet.)

Following the adoption of a policy of taking all practicable measures to increase income and decrease expenditures without curtailing desirable services, the directors voted to charge a suitable member registration fee at general and District meetings, beginning with the 1948 Midwest general meeting, in addition to a nonmember registration fee, not applicable to the immediate families of members or to Student members, at least 50 per cent higher than the member fee.

APPOINTMENTS

The appointment of a representative of the Institute on the Washington Award Commission for the term of two years beginning June 1, 1948, was referred to the president with power. (President Hull subsequently appointed Frank V. Smith, of Chicago.)

The nomination, for election by the board of trustees of United Engineering Trustees, Inc., of a representative on the Engineering Foundation Board for the term of four years beginning in October 1948, was referred to the president with power. (President Hull later designated C. G. Suits, of Schenectady, N. Y.)

Approval was given to appointment by the president of the following members of the committee of tellers to canvass and report upon the ballots cast for the constitutional amendments and for the election of Institute officers: H. B. Margolis (*chairman*), E. J. Balsdon, Alfred Kahn, L. G. McDowell, F. C. Roberts, G. M. Smith, and D. E. Sullivan.

Spokane Host to Pacific General Meeting

Spokane Falls as seen through the Monroe Street bridge in Spokane, Wash., site of the 1948 AIEE Pacific general meeting to be held August 24–27 with headquarters at the Davenport Hotel

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full, formal text of a technical paper including discussion if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb '47, pp 190–1	Feb '47, pp 33A and 34A
North Eastern District	Apr '47, pp 401–02	June '47, pp 55A and 56A
Summer General	June '47, pp 607–14; July '47, p 708	
Pacific General	Aug '47, pp 840–2	Dec '47, pp 55A and 56A
Middle Eastern District	Sept '47, pp 925–7	
Midwest General	Nov '47, pp 1125–8	
Winter ('48)	Jan '48, pp 76–87	Apr '48, pp 49A and 50A

Upon recommendation of the Sections committee, the boundary between the Toronto and Montreal Sections was changed to the interprovincial boundary between Ontario and Quebec from James Bay to the Ottawa River, down the Ottawa River and along the western boundaries of the Counties of Renfrew, Lanark, and Leeds to the St. Lawrence River. Also, the establishment of a new Section at Richland, Wash., with territory as follows was authorized:

Columbia, Walla Walla, Benton, Franklin, Yakima counties in Washington (transferred from the Spokane Section), and Umatilla county in Oregon (transferred from the Portland Section).

Upon recommendation of the Standards committee, the directors approved the appointment of E. I. Pollard as an additional AIEE representative on the AIEE-American Society of Mechanical Engineers joint committee on steam turbine generators, and the appointment of the following additional representatives and alternates of the Institute on AIEE-Edison Electric Institute-National Electrical Manufacturers Association joint committee on insulation co-ordination:

Representatives—I. W. Gross, S. E. Schultz, J. J. Taylor, T. G. A. Sillers.

Alternates—F. J. Vogel, R. A. Hopkins, H. W. Collins, J. E. Clem, and C. F. Wagner.

The following actions were taken upon recommendation of the committee on planning and co-ordination:

Voted to hold the 1951 summer general meeting in Toronto, Ontario, Canada, June 25–29.

Changed the dates of the previously authorized 1950 winter general meeting to January 30–February 3.

Voted to abolish, at the end of the present administrative year, the grouping of general committees in the administrative group.

BYLAWS

The following amendments to the bylaws were adopted upon recommendation of the committee on constitution and bylaws:

Section 22.—Fourth paragraph, line 6, changed to read:
To insure that full consideration be given to all suggestions from the general membership, they must be in the hands of the secretary of the committee by December 15.

Section 32.—Last phrase changed, by the addition of the underlined parts, to read:
Also, in order to encourage co-operation between Sections and Branches, *a member of the Sections Committee who is resident in the District* and the chairman of the District committee on student activities.

Section 36.—First sentence changed to read:
A petition for the formation of a Section shall be signed by not less than 50 members residing within the territorial limits hereinafter prescribed.

The following resolutions were adopted upon recommendation of the Standards committee and the committee on constitution and bylaws:

RESOLVED: That the Standards committee is hereby authorized to give final approval to standards in the name of the Institute unless one or more members serve notice of dissent with intention to appeal to the board of directors. In such event the committee shall notify the board of directors and submit a full report of the case. The Standards committee shall report to the board of directors all new and revised Standards. The committee shall submit to the board of directors all policy questions, including that of undertaking standards in new fields.

RESOLVED: That the Standards committee is hereby authorized to appoint AIEE representatives to serve on standardization committees for which this Institute is sponsor, or on such delegations for standardizing purposes which will serve under the sponsorship of other societies or organizations (American Standards Association, ASME, Institute of Radio Engineers, and so forth), with the understanding that such appointments will be promptly reported to the board of directors.

MISCELLANEOUS

The committee on electric heating reported the establishment of an AIEE, IRE, and NEMA joint co-ordinating committee on commercial induction and dielectric heating apparatus, on which the AIEE representative will be the chairman of the committee on electric heating. This action was approved.

Report was made of the decision of the members of the American Co-ordinating Committee on Corrosion to disband the committee and turn over its functions, together with its files and cash assets, to the National Association of Corrosion Engineers. This decision was concurred in by the AIEE representatives on the committee. The directors voted their approval of this action.

The president was authorized to appoint

Future AIEE Meetings

Pacific General Meeting
Spokane, Wash.
August 24–27, 1948
(*Final date for submitting papers—June 10*)

Middle Eastern District Meeting
Hotel Statler, Washington, D. C.
October 5–7, 1948
(*Final date for submitting papers—July 21*)

Midwest General Meeting
Schroeder Hotel, Milwaukee, Wis.
October 18–22, 1948
(*Final date for submitting papers—August 3*)

Southern District Meeting
Birmingham, Ala.
November 3–5, 1948
(*Final date for submitting papers—August 20*)

AIEE Conference on Electronic Instrumentation in Medicine and Nucleonics
New York, N. Y.
November 29–December 1, 1948

AIEE Conference on Electric Welding
Detroit, Mich.
December, 1948

AIEE Conference on High-Frequency Measurements
Winter, 1948

Winter General Meeting
Pennsylvania Hotel, New York, N. Y.
January 31–February 4, 1949
(*Final date for submitting papers—November 16*)

AIEE Conference on Electron Tubes
March, 1949

AIEE Conference on the Rubber and Plastics Industry
Akron, Ohio
March, 1949

Southwestern District Meeting
Dallas, Tex.
April 20–22, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949

View of the United States Capitol, Washington, D. C., host city for the Middle Eastern District meeting in October (see page 710)

two AIEE members of the National Engineers Consultative Committee being organized by the Engineers Joint Council to carry on the functions of the Consultative Committee to the Secretary of State and the former National Engineers Committee and to handle requests for aid from administrative agencies of the federal government.

The directors accepted an invitation of the American Mathematical Society to act as cosponsor of the society's Symposium on Applied Mathematics to be held at the Massachusetts Institute of Technoogy, July 29–31, 1948, and designated the committee on basic sciences to co-operate in this symposium.

Action was taken slightly changing the recently revised rules for the award of Institute prizes by providing for either oral, written, or oral and written presentation of papers in the District Branch prize competition, instead of oral presentation only as required in the revision which was published in the December 1947 issue of *ELECTRICAL ENGINEERING.*

Other matters were discussed, reference to which may be found in this or future issues of *ELECTRICAL ENGINEERING.*

Present at the meeting were

President—B. D. Hull, Dallas, Tex.

Past President—C. A. Powel, East Pittsburgh, Pa.

Vice-Presidents—J. H. Berry, Norfolk, Va.; G. W. Bower, Haddonfield, N. J.; O. E. Buckley, New York, N. Y.; D. I. Cone, San Francisco, Calif.; R. F. Danner, Oklahoma City, Okla.; E. W. Davis, Cambridge, Mass.; I. M. Ellestad, Omaha, Nebr.; D. G. Geiger, Toronto, Ontario, Canada; T. G. LeClair, Chicago, Ill.

Directors—P. L. Alger, Schenectady, N. Y.; W. L. Everitt, Urbana, Ill.; J. F. Fairman, New York, N. Y.; R. T. Henry, Buffalo, N. Y.; M. J. McHenry, Toronto, Ontario, Canada; A. C. Monteith, East Pittsburgh, Pa.; J. R. North, Jackson, Mich.; D. A. Quarles, New York, N. Y.; Elgin B. Robertson, Dallas, Tex.; Walter C. Smith, Palo Alto, Calif.; E. P. Yerkes, Philadelphia, Pa.

Treasurer—W. I. Slichter, New York, N. Y.

Secretary—H. H. Henline, New York, N. Y.

Middle Eastern District to Meet in Washington, D. C.

A well-balanced program of broad interest has been planned for the forthcoming Middle Eastern District meeting to be held at the Statler Hotel, Washington, D. C., October 5–7, 1948. A number of technical sessions covering air transportation, communications, electric instruments and engineering developments, marine transportation, nuclear engineering, naval test, power, rural electrification, and joint sessions with Illuminating Engineering Society and Industrial Research Engineering are being scheduled.

Inspection trips to the David Taylor Model Basin, the Bureau of Standards, Carnegie Institution Laboratory for Atomic Research, National Airport, as well as sightseeing trips, have been planned.

The complete program is scheduled to appear in the September issue of *ELECTRICAL ENGINEERING.*

Midwest General Meeting to Be Held in Milwaukee

A technical program of broad interest is in prospect for the Midwest general meeting to be held in Milwaukee, Wis., October 18–22, 1948. Headquarters for the meeting will be in the Schroeder Hotel.

When the Midwest general meeting first was established, one of the objectives was to relieve the congestion of the winter meetings. Preliminary plans indicate that this objective will be fulfilled as approximately 36 technical sessions are contemplated in three broad fields—communication and science, power, and industry. Plans also are being made for a joint session by the committee on education in co-operation with the committee on Student Branches.

In addition to the technical activities, there will be the usual social events, entertainment, and inspection trips.

Institute Prizes for 1947 Reported by Award Committee

The AIEE committee on award of Institute prizes has submitted a report on the award of Institute prizes for the papers presented during the year 1947. The papers selected for the awards and honorable mentions in the several classifications are as follows:

Best Paper Prize in the Field of Engineering Practice
"Frequency Shift Telegraphy—Radio and Wire Applications," J. R. Davey, A. L. Matte, Bell Telephone Laboratories, Inc.

(*Honorable mention*) "Generating Reserve Capacity Determined by the Probability Method," Giuseppe Calabrese, Consolidated Edison Company of New York, Inc.

Best Paper Prize in the Field of Theory and Research
"The Hysteresis Motor—Advances Which Permit Economical Fractional Horsepower Ratings," H. C. Roters, Fairchild Camera and Instrument Corporation

Prize for Initial Paper
"The Probable Breakdown Voltage of Paper Dielectric Capacitors," Hamilton Brooks, Westinghouse Electric Corporation

Prize for Branch Paper
"The Phantastron Single-Tube Control Circuit," James R. McDade, Southern Methodist University (presented at the Southwest District Student Branch conference, University of New Mexico, May 6, 1947).

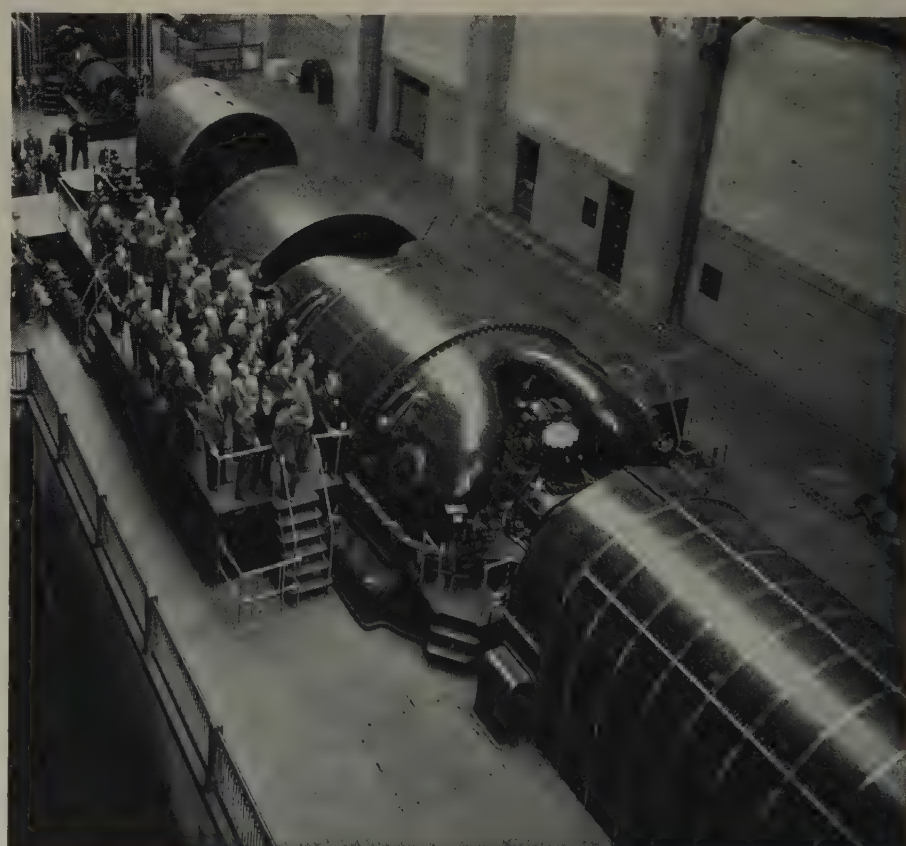
(*Honorable mention*) "Theory and Operation of Electric Machines for Solving Linear Equations," Dale Rummer, Kansas University (presented at the Student Branch meeting held at Kansas University, April 16, 1947).

A number of the papers considered were of a high order and the decision between the choice of leading papers in several of the classes were very close. The valuable assistance of the technical committees and their reviewers in nominating and grading the many papers is acknowledged by the committee, of which H. M. Turner is chairman.

Pittsburgh Section Organizes New Subsection at Johnstown

The formation of a new AIEE Subsection was announced recently with the organiza-

Midwest Meeting Inspection Trip



Among many inspection trip opportunities for AIEE members at the coming Midwest general meeting in Milwaukee, Wis., October 18–22, is the Wisconsin Electric Power Company's Port Washington power plant. Here, engineers are inspecting the Allis-Chalmers 80,000-kw turbogenerator units number 1 (in the foreground) and number 2

tion of the Johnstown Subsection of the AIEE Pittsburgh (Pa.) Section. The inaugural dinner held on March 29 in Johnstown's Fort Stanwix Hotel was attended by more than 75 members of the profession, among whom were four members of the Pittsburgh Section who were present to aid the local group in forming the new unit. Attending in this capacity were A. C. Monteith, chairman of the Pittsburgh Section; A. A. Johnson, publicity director for the Pittsburgh Section; H. H. Wagner, secretary-treasurer of the Pittsburgh Section; and F. H. Schlough, technical program director of the Pittsburgh Section.

A. M. Baker, assistant system electrical engineer of the Pennsylvania Electric Company, was elected chairman of the newly-formed Johnstown Subsection at the introductory dinner-meeting. Other officers elected were

William R. Wood, Berwind-White Coal Mining Company, *vice-chairman;* Wesley Rohrer, University of Pittsburgh, *secretary;* C. A. Anderson, Pitt Center, *treasurer.*

Also elected were the following as directors:

W. C. Sontum, Pennsylvania Electric Company, and Carl Weyandt, Syntron Company, *3-year terms;* Eric L. Anderson, Bethlehem Steel Company, and R. R. Mathias, General Electric Supply Corporation, *2-year terms;* Frank D. Piazza and D. R. Pattison, both of Pennsylvania Electric Company, *1-year terms.*

In addition the following committees were appointed:

Membership: R. R. Mathias (*chairman*), Don Black, James C. Browning, C. E. Wissinger, A. W. Wilson, A. E. Molinski

Social: Frank D. Piazza (*chairman*), A. M. Dawson, Ralph Hunter

Student activity: Robert V. Baum (*chairman*), R. C. Hitchcock

Technical program: J. M. Kadetsky (*chairman*), Eric L. Anderson, James C. Browning, C. A. Anderson, C. S. Smith

Publicity: Frank D. Piazza (*chairman*), A. M. Dawson, B. H. Drum

Middle Eastern District Holds Branch Prize Paper Contest

Thd AIEE Middle Eastern District (number 2) held its first District Branch prize paper competition, under the new Institute prize paper rules, at Columbus, Ohio, Friday and Saturday, May 14 and 15, 1948. Ohio State University acted as host. Seventeen District number 2 Branch prize paper winners participated in the competition.

Professor Kimberly, counselor of Ohio State Student Branch, acted as chairman of the contest meetings, and the students of the Ohio State Student Branch were responsible for the meeting arrangements. Friday morning was devoted to registration and inspection of the university's engineering department. Co-ordination of this contest with Ohio State's Annual Engineers Day provided many extra events of interest to all who attended.

Presentations, limited to 20 minutes each, were scheduled for Friday afternoon and Saturday morning. A dinner for the contestants, counselors, Institute officials, and Students attending was on Friday evening, at which talks were given by AIEE President Hull and Vice-President Bower. The ten dollar checks and the certificate of awards were presented to each Branch prize contest winner by District Secretary Muir. A feature of this dinner meeting was a conference on the merits of Student participation in AIEE work, led by Vice-President Bower. Following the dinner, many of the visitors attended the regular meeting of the AIEE Columbus Section at Battelle Memorial Institute. The others enjoyed the student show by Ohio State's Quadrangle Jesters.

The meeting was closed by a luncheon held in the Ohio Union Building on the campus. At this luncheon an enthusiastic talk on Student activities was presented by Professor J. L. Beaver, District chairman of the committee on Student activities. Professor A. J. B. Fairburn, acting as chairman of the judging committee, announced the winner, John N. Grace of Carnegie Institute of Technology, for his paper on, "Electroencephalography," the science of the measurement of the potentials generated within a human body, one purpose of which is the location of brain tumors. The contest was extremely close, and the committee was obliged to award four honorable men-

Guests at Steinmetz Memorial Lecture Dinner

On May 20, 1948, at Union College Memorial Chapel, Schenectady, N. Y., Philip Sporn, president of the American Gas and Electric Service Corporation, delivered the 1948 Steinmetz Memorial lecture, 21st in a series of lectures sponsored by the AIEE Schenectady Section to honor the memory of its first chairman, Charles P. Steinmetz. Shown here is a group attending dinner prior to the lecture, representing the AIEE, the General Electric Company, and prominent local citizens. They are (first row, left to right) H. W. Bibber; P. L. Alger; J. P. Smith; R. P. Wagner; Philip Sporn, Steinmetz Memorial lecturer; B. H. Caldwell, Schenectady Section chairman, 1947–48; E. F. W. Alexanderson; G. B. Warren; D. H. Ware; D. C. Prince. (Second row, left to right) R. Treat, Schenectady Section chairman, 1929–30; E. H. Bancker; L. F. Lewis; J. C. Page, Schenectady Section secretary, 1946–48; H. Popper; D. W. McLenegan, Schenectady Section chairman, 1933–34; T. M. Linville, Schenectady Section chairman, 1942–43; L. A. Umansky, Schenectady Section chairman, 1944–45; Laydon Lansing; H. M. Sliter; C. S. Coggeshall; H. F. McRell; F. M. Roberts. (Third row, left to right) H. J. Finison; A. K. Bushman; J. O. Roser; R. W. Beard; R. V. Shepherd, Schenectady Section chairman, 1946–47; T. F. Barton; J. W. Belanger; P. H. Light, Schenectady Section chairman, 1945–46; L. T. Rader. (Fourth row, left to right) H. S. Hubbard; J. L. R. Hayden; F. K. McCune; T. Johnson; Newell Freeman; E. E. Johnson, Schenectady Section chairman, 1932–33; D. E. Garr, Schenectady Section treasurer; W. V. O'Brien; W. P. Smith

tions to: Glenn E. Wehl, William J. J. Klein, Lawrence F. Kalnoskas, and H. M. Paiss.

The District Branch Prize winner, John N. Grace, will receive a cash prize of $25 and a certificate of award, which will be presented to him during the Middle Eastern District meeting to be held in Washington, D. C., October 5–7, 1948. The winner also will present an abstract of his paper at one of the sessions during the summer general meeting at Mexico City, June 21–25, 1948. The travel allowance of nine cents per mile one way, plus a reasonable hotel and meals expense for the official duration of the meeting, is provided by the Member-for-Life Fund of the Institute for this trip.

The prize papers judging committee, which was appointed by the District coordinating committee, consisted of A. J. B. Fairburn, R. C. McMaster, A. F. Puchstein, and H. R. Weed. The arrangements, hotel reservations, and other details of the meeting were handled by the Students of the Ohio State Student Branch under the supervision of Robert Chappell, chairman of the Student Branch, and L. V. Hedges, chairman of the program committee.

The following 17 Branch prize papers were presented:

"Applications of Electricity in the Rubber Industry," John Popa, University of Akron

"Mass Spectroscope," Richard W. Lowrie, Bucknell University

"Electroencephalography," John N. Grace, Carnegie Institute of Technology

"The Supersonigator," Glenn E. Wehl, Case Institute of Technology

'The Adjustment of Antennas and Transmission Lines," Charles C. Porch, University of Delaware

"Saturable Reactors," H. M. Paiss, Drexel Institute of Technology

"Wave Shaping Circuits and Their Uses," William J. J. Klein, George Washington University

"Electrical Welding and Cutting Under Water," Henry M. Boettinger, Johns Hopkins University

"Electricity and the Human Body," Lawrence F. Kalnoskas, Lafayette College

"The Economic Location of a Generator Station," R. D. Wallick, Lehigh University

"Servomechanism Theory," Charles A. Morell, University of Maryland

"Loran," Robert Redick, Ohio Northern University

"Electrical Aspects of the Flux Gate Compass System," Randall H. Rice, Pennsylvania State College

"An Aircraft Landing System," Walter McGough, Jr., University of Pittsburgh

"The Nier Mass Spectrometer," George C. Sponsler Princeton University

"The Operation of a Hard Tube Pulse Modulator and Difficulties Encountered in Experimental Application," Leo Woerner, Swarthmore College

"Lightning," Robert Muldoon, Villanova College

Two other Branch prize papers and the winners who were unable to attend the District prize paper competition were

"High-Frequency Heating," Alfred W. Duerig, University of Pennsylvania

"Industrial Applications of Radar," Robert Luck Hall Jr., West Virginia University

District 6 Student Conference Held at University of Denver

The District 6 Student Branch conference was held at the University of Denver, Denver, Colo., April 16–17, 1948. After an informal get-acquainted session in the morning, the formal program began at 1:00 p.m. April 16, 1948, in the memorial chapel, University of Denver campus, with J. E. Martin, presiding.

Mr. Martin presented C. M. Knudson, dean of engineering, University of Denver, who welcomed all of the District officers, Student Branch counselors, visiting students, and guests to the University of Denver and freely offered the facilities for the use of the conference. Dean Knudson expressed sincere interest in the doings of the Student Branches of AIEE.

Mr. Martin then presented the visiting District and Section officers and also presented E. L. Golightly, chairman of the University of Denver Student Branch, who presided at the presentation of the Student Branch papers.

The committee of judges appointed by the Denver Section present during the presentation of the papers included L. M. Robertson, Hubert Sharp, and H. A. Morgan. The following papers were presented:

"Ours Is the Responsibility," Fred J. Berkenkamp, University of Wyoming, Laramie, Wyo.

"Radiography in the Electrical Engineering Laboratory," R. C. Clark, South Dakota School of Mines and Technology, Rapid City, S. Dak.

"Super-High-Frequency Measurements," John L. Grigsby, University of Colorado, Boulder, Colo.

At the conclusion of the third paper, the conference was adjourned until the evening.

At 6:30 p.m. in the Edelweiss banquet room, Denver, Colo., all of the members of the District 6 Student Branch conference attended a Denver Section meeting. L. L. Patterson of the Denver Section presided.

Following dinner, I. M. Ellestad, vice-president of AIEE District 6, addressed the group on a subject dealing generally with the background and history of the AIEE, what it means today and what it can mean to the undergraduate engineer during his professional career. The group also was addressed by Professor Marion J. Smith of the University of Colorado on the subject "The Improvement of the Starting Torque of Synchronous Motors." At approximately 9:30 p.m. the meeting was adjourned.

During the second day of the conference there was held a business meeting of Branch counselors, District vice-president, and secretary, at the memorial chapel of the University of Denver, and Vice-President Ellestad presided.

Among other items, it was decided that the next District 6 Student Branch conference be held at South Dakota School of Mines and Technology and that Professor J. O. Kammerman be named District Student Branch counselor for the coming year. It also was agreed that the District Student Branch counselor to attend the summer meeting as a representative of District 6 should be the outgoing District counselor on Student affairs (J. E. Martin).

Vice-President Ellestad discussed in some detail the Student Branch prize rules now in effect, the good features and the bad features, and so forth. It was the concensus of opinion of this group that a Student Branch paper should be both written and oral. A discussion of the grading system followed. It was agreed that the AIEE Sections committee be advised that the District 6 Student Branch conference would like to see the grading changed to a rating of approximately *3* for the written and *1* for the oral presentation. It was believed that the present rules allowing weight for the written paper and the oral presentation, allowed too much emphasis to be put on the oral presentation and that a ratio of approximately three to one would be more proper, and still recognize the fact that the oral presentation was of considerable importance.

It was agreed that the next Student Branch District conference would be held in the spring of 1949, approximately April 21–23 to be later confirmed as to the exact date after canvass of the Student counselors and subject to approval of the District 6 executive committee. It further was agreed and emphasized by Vice-President Ellestad that the papers should be in the hands of the judges for the written portion positively not later than three weeks in advance of the date of the Student Branch Conference in order to allow those judges ample time to judge the papers competently and give all entries full consideration.

It developed that only the following two schools definitely had established their Student Branch counselors for the next year: Professor C. H. Chinburg, Colorado State College (of Agriculture and Mechanic Arts), Fort Collins, Colo., and Professor J. O. Kammerman, South Dakota School of Mines and Technology, Rapid City, S. Dak. It was urged that the rest of the schools quickly determine their counselor and advise the District secretary. The meeting then was adjourned.

While the foregoing meeting was in progress the students attending the Student Branch conference were inspecting the electrical engineering laboratory at the University of Denver with representatives of the University of Denver AIEE Student Branch acting as guides.

During the morning also, in the memorial chapel of the University of Denver with E. L. Golightly presiding, two papers were presented:

"Proper Selection of Employees by Public Utilities," Don Anderson and Jack Smith, University of Wyoming, Laramie, Wyo.

"A Class C Amplifier for Instructional Use," Frost, University of Nebraska, Lincoln, Nebr.

After lunch, the entire group was invited to take one of the two inspection trips planned, both of which proved to be extremely interesting. About one-half of those present went by bus to the *KLZ* broadcasting transmitter at Englewood, Colo., at which time the station employees explained the equipment in use and the various systems used. The remainder of the group took advantage of the other option and were taken by bus to see a newly installed mercury arc rectifier in a substation of the Denver Tramway Company.

Both groups then were taken to one of the

main substations of the Public Service Company of Colorado where L. M. Robertson, H. F. Gidlund, and others did a very competent job of guiding. Upon completion of the inspection trips, the entire party was returned to the University of Denver campus.

Later, again in the memorial chapel, Vice-President Ellestad (who presided) announced that after due consideration by the judges of the oral presentation of the papers and in conjunction with the grading of the judging committee from the Omaha Section for the written portion (Art Lof, chairman, C. W. Minard, and R. J. Berti) the following winners had been determined:

First prize ($25 offered by AIEE headquarters): John L. Grigsby, University of Colorado

Second prize (provided by Denver Section and Nebraska Section): Fred J. Berkenkamp, University of Wyoming

Third prize (provided by Denver Section and Nebraska Section): R. C. Clark, South Dakota State School of Mines and Technology

During discussion it developed that more than 200 visiting students, faculty members, District officers, and Section members had registered for the Student conference and it was believed that a great deal of the interest was aroused by the exceptionally good inspection trips planned by the Student conference committee.

Mr. Ellestad asked for a report of the resolutions committee with the request that its report be incorporated in the minutes of this Student Branch conference. When the report was accepted the conference was adjourned.

PERSONAL NOTES.......

M. G. Crosby (M '43) has founded the firm of Crosby Laboratories at Mineola, N. Y., where he will conduct a radio-electronic consulting practice. He formerly was a member of the firm of Paul Godley Company, Upper Montclair, N. J. Mr. Crosby was born at Elroy, Wis., on September 17, 1903, and received the degree of bachelor of science in electrical engineering from the University of Wisconsin in 1927 and a professional electrical engineering degree in 1943. From 1925 to 1944 he was research engineer with the Radio Corporation of America in the communications division of RCA Laboratories, specializing in frequency and phase modulation, and point-to-point reception. In 1943–44 he served as an expert technical consultant to the Secretary of War, and also on the Radio Technical Planning Board. He is the author of a considerable number of technical articles, and the holder of many patents. Mr. Crosby was awarded a fellowship in the Institute of Radio Engineers for his technical contributions; he is a member of the board of directors of that organization, and a fellow of the Radio Club of America.

A. E. Silver (A '07, F '26, member for life) consulting electrical engineer, Ebasco Services, Inc., New York, N. Y., has been named associate consultant and is retiring from active service. Entering upon an electrical engineering course at the University of Maine, Mr. Silver was graduated with the class of 1902, and then entered the test department of the General Electric Company at Schenectady, N. Y. Following experience with the Raleigh (N. C.) Electric Company and the Carolina Power and Light Company, in 1910 he became electrical engineer of the Electric Bond and Share Company, parent of Ebasco Services, Inc. He served for many years on AIEE committees on power generation and power transmission and distribution, and was active in the work of the National Electric Light Association, now the Edison Electric Institute. Mr. Silver was among those receiving the 1931 AIEE national prize for best paper in engineering practice. He has served continuously since 1924 on the AIEE transmission and distribution committee.

J. K. Hodnette (A '25 F '42) manager, transformer division, Westinghouse Electric Corporation, Sharon, Pa., has been elected a vice-president of the company. He also will retain his present post. He has been with the company since 1923, the year following his graduation as a mechanical engineer from Alabama Polytechnic Institute. Starting with the company at East Pittsburgh, Pa., in 1925, he was assigned to transformer engineering and design at Sharon. One of his achievements was the development of a power distribution transformer claimed to be completely self-protected against lightning and electrical overload, for which the National Association of Manufacturers in 1940 named him "modern pioneer of the American frontier of industry." Mr. Hodnette became engineering manager of the transformer division in 1940, and manager in 1946. He is the author of numerous technical articles.

Carroll Stansbury (M '35, F '38) electrical engineer, Bureau of Ships, United States Navy Department, Washington, D. C., has been appointed to the electronics division of the National Bureau of Standards, Washington, where he will do research in the engineering electronics laboratory. A graduate (1921) of Johns Hopkins University, he was senior development engineer with Cutler-Hammer, Inc., Milwaukee, Wis., when he accepted an appointment with the Bureau of Ships, in which he supervised the design and installation of equipment for radio-controlled vessels and served on industrial committees concerned with electric motors, control apparatus, and insulation. From 1946 until this year he was at the Taylor Model Basin, where he experimented with acoustic devices for the Navy. Mr. Stansbury holds many patents in the fields of motor control, industrial electronics,and resistance welding, and has served on the AIEE marine transportation committee and the AIEE electric welding committees.

G. R. Bastedo (A '34) has been appointed to the staff of the National Bureau of Standards, Washington, D. C., where he will work as electronics engineer for the guided missile section. Mr. Bastedo attended Pratt Institute and New York University, receiving the degree of bachelor of science in electrical engineering in 1936. In 1943 he was commissioned in the United States Navy, and was a lieutenant at the time of his discharge in 1946. He served as project officer on a guided missile project for the Bureau of Ordnance Experimental Unit stationed at the National Bureau of Standards from 1944 to 1946, when he became a project engineer for the research and development division, Bureau of Ordnance, Navy Department.

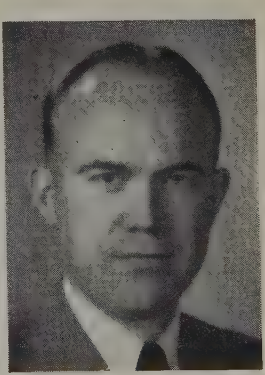
Robert E. Pierce (A '21, F '47) who has been electrical engineer in the engineering department of Ebasco Services, Inc., New York, N. Y., has been appointed consulting electrical engineer. He is a graduate of Purdue University, class of 1918; following graduation he entered the operating department of the Utah Power and Light Company. After becoming electrical engineer for the company, he transferred, in 1927, to the engineering department of Electric Bond and Share Company, which later became Ebasco Services, Inc.

J. K. Hodnette

R. E. Pierce

G. R. Bastedo

Carroll Stansbury



M. G. Crosby

G. L. Haller (M '45) has been named dean of the school of chemistry and physics at the Pennsylvania State College, State College. After graduating from Mercersburg Academy in 1924, Doctor Haller attended Pennsylvania State College where he received four degrees: a bachelor of science in electrical engineering, the degree of electrical engineer, and a master of science and a doctor of philosophy in physics. In 1935 he became a civilian radio engineer for the War Department at Wright Field, Ohio, and in 1942 was commissioned a major in the Signal Corps, later being assigned to the Air Corps. In 1945 he was awarded the Legion of Merit for research and development of radar countermeasures for the Army Air Forces. Doctor Haller was separated from the Army in 1946 as a colonel and returned to Pennsylvania State College as assistant dean of the school of chemistry and physics; in 1947 he was named acting dean of the school. He is a member of many technical and scientific societies, and is the author of numerous papers.

C. B. Mirick (A '08, F '47) has retired as special assistant to technical information officer at the Naval Research Laboratory, Washington, D. C. He was born at Athens, Ohio, July 26, 1881, and was graduated from Cornell University in 1905 with the degree of mechanical engineer in electrical engineering. He then was employed by the National Electrical Supply Company, Washington, and was successively superintendent of construction, chief engineer, and vice-president. Since 1922 he had been with the Naval Research Laboratory; during 1944–46 he was consultant as special assistant to the superintendent of the radio division of the laboratory, becoming editorial adviser in 1946. Recently he received a Naval award and the Presidential award for his work with radar and remote control devices. During World War I he served as a commissioned officer in the Navy. He has been a member of the AIEE air transportation committee since 1942.

V. P. Hessler (A '20, F '43) has resigned as professor and head of the electrical engineering department at the University of Kansas, Lawrence, to become professor of electrical engineering at the University of Illinois, Urbana. A graduate of Oregon State College with a degree of bachelor of science in electrical engineering in 1926, he received the degree of master of science in electrical engineering from Iowa State College in 1927 and that of doctor of philosophy in electrical engineering in 1934. He was an instructor at Iowa State College, Ames, from 1927 to 1936, and an assistant professor unitl 1938, when he became a member of the faculty of the University of Kansas. Professor Hessler was awarded the 1946 AIEE best paper prize in the field of public relations and education. He is a member of the American Society for Engineering Education.

T. J. Higgins (A '40, M'47) professor of electrical engineering at the Illinois Institute of Technology, Chicago, has been appointed to a full professorship in the college of engineering at the University of Wisconsin, Madison. Professor Higgins received his degree in electrical engineering from Cornell University in 1932, and a master's degree in mathematics from the same institution in 1937. He earned his doctor of philosophy degree in electrical engineering at Purdue University in 1941. While at Purdue University, Doctor Higgins was an instructor in electrical engineering. In 1941–42 he was an assistant professor of electrical engineering at Tulane University, New Orleans, La. The following year he accepted an associate professorship at Illinois Institute of Technology, and was promoted to full professor in 1947. He is the author of a number of AIEE papers.

F. W. Crandall (A '41) has been appointed manager of the Washington, D. C., office of Ebasco Services, Inc. Following his graduation from Cornell University, Mr. Crandall was for several years engaged in various branches of engineering work, and in 1939 was made executive secretary of the National Defense Power Committee; in 1942 he was commissioned a major in the Army of the United States and appointed as the Army's representative on power matters on the Army and Navy Munitions Board. Later he was promoted to lieutenant colonel and was attached to the United States Military Mission to Moscow in 1944. Before joining Ebasco Services in 1947, he remained in the Office of the Chief of Staff as a civilian, initiating plans and procedures for peacetime power activities.

E. O. Shreve (A '06) has retired as vice-president of the General Electric Company, New York, N. Y., after 44 years of service. Mr. Shreve is president of the United States Chamber of Commerce, and recently received the James H. McGraw Award manufacturers medal for 1947 as announced in *ELECTRICAL ENGINEERING* for May 1948, page 502. A graduate of Iowa State College, his association with the General Electric Company began in 1904 as student engineer in the company's test course. After a succession of various positions, he was made vice-president in charge of sales in 1934 and vice-president in charge of customer relations in January 1945. Mr. Shreve is director of the General Electric Supply Corporation and a trustee of the National Electrical Manufacturers Association.

R. H. Knowlton (A '12) who has been executive vice-president, Connecticut Light and Power Company, Hartford, has been elected president. He is an engineering graduate of Cornell University, and first became associated with the company in a consulting capacity in 1917. He was made assistant to the president in 1926, and vice-president in charge of sales and public relations the following year. In 1935 he was elected a director and four years later became executive vice-president. He is a member of Edison Electric Institute.

William Crombie White (A '37, M '42) director of the day division of Northeastern University, Boston, Mass., recently was elected president of the Engineering Societies of New England. An honor graduate of Northeastern University in 1925, he has been a member of the faculty since 1926, becoming dean of the College of Engineering in 1941 and assuming his present title in 1945. From 1942 until 1945 Dean White was regional adviser to the United States Office of Education in the Engineering Science and Management War Training Program.

E. W. Starr (A '28, M '36) who has been acting head of the electrical engineering department, The Cooper Union, New York, N. Y., has been appointed permanently to that office. A graduate of Cornell University in 1925, he has been on the Cooper Union faculty since 1931. Formerly he taught at Worcester (Mass.) Polytechnic Institute.

C. M. Lynge (M '22) formerly manager of manufacturing, appliance and merchandise department, General Electric Company, Bridgeport, Conn., has been appointed manager of employee and community relations for both that department and the newly formed construction materials department.

C. W. Falls (A '21, M '45) engineer, motor division, industrial engineering department, General Electric Company, Schenectady, N. Y., has been appointed manager, commercial engineering division, general sales divisions.

Felix Wunsch (A '13, M '29) technical adviser, Leeds and Northrup Company, Philadelphia, Pa., has retired after nearly 43 years with the company. He first entered the employ of the company in 1905 and since 1910 had been engaged for the most part in electrical design, a period in which he developed and perfected several inventions.

J. C. Armor (A '08, F '42) head of the power transformer design section for the Allis-Chalmers Manufacturing Company, Pittsburgh, Pa., has been appointed consulting engineer. Mr. Armor entered the employ of the Pittsburgh Transformer Company in 1920 as design engineer, and continued with radio and transformer design and development work after the company was acquired by the Allis-Chalmers Company in 1927. He holds a number of basic patents including one on a magnetic amplifier.

OBITUARY • • • • • •

Edwin Woodworth Hamlin (A '35, M '42) professor of electrical engineering, Cornell University, Ithaca, N. Y., died April 27, 1948. Doctor Hamlin was born at New York, N. Y., July 21, 1905, and received the degrees of bachelor of science (1926), master of science (1928), and doctor of philosophy (1932) at Union College. He was an instructor there from 1932 to 1935, then was successively assistant and associate professor at the University of Kansas, Lawrence, from 1935 to 1939; he then became professor of electrical engineering and director of the electrical engineering research laboratory at the University of Texas, Austin. There he directed a program which studied the angle of arrival from outer space of microwaves, a project that was sponsored by the Office of Naval Research under the auspices of the National Defense Research Council. Doctor Hamlin

had joined the Cornell faculty effective September 1, 1947. He was a member of the Institute of Radio Engineers, the American Association of University Professors, and was serving as secretary of the electrical engineering division of the American Society for Engineering Education at the time of his death. As director of the microwave astronomy project at Cornell University, Doctor Hamlin directed studies being made of extraterrestrial electromagnetic radiations in the frequency range normally used for radio communications and was in charge of construction of the university's radio astronomical observatory. At the University of Kansas he was AIEE Student Branch counselor from 1936 to 1939. He served on the AIEE communication committee, 1942–44.

William Wilson (M '23) professor of physics, North Carolina State College, Raleigh, and former assistant vice-president of Bell Telephone Laboratories, Inc., died May 6, 1948. Doctor Wilson was born at Preston, England, March 29, 1887, and received his technical education at the University of Manchester and at the University of Cambridge. He was engaged in research work in electron physics at these universities from 1907 to 1912, when he became a lecturer in physics at the University of Toronto in Canada. In 1914 he entered the research laboratory of the Western Electric Company at New York, N. Y., working on electronics. During World War I he had charge of the Western Electric Company's manufacture of vacuum tubes for the government, and in 1918 became responsible for vacuum tube research, development, design, and manufacture. In 1925 Bell Telephone Laboratories was formed, and Doctor Wilson also took charge of radio research activities; in 1927 he was made assistant director of research. In 1936, he was appointed assistant vice-president in charge of personnel and publication. He retired in 1942, and accepted the appointment at the University of North Carolina in 1946. Doctor Wilson represented AIEE on the sectional committee on radio of the American Standards Association, and was a member of the American Physical Society and the Institute of Radio Engineers. He received the medal of honor of the last named organization in 1943 "in recognition of distinguished service in radio communication."

George Herbert Rockwood, Jr. (A '26, M '34) professor of electrical engineering, University of Illinois, Urbana, died recently. He was born at Chicago, Ill., April 14, 1902. and received the degree of bachelor of science from Dartmouth College in 1924' He received the degrees of bachelor of science and master of science from Massachusetts Institute of Technology in 1927, after which he entered the employ of the Western Electric Company. He transferred to the vacuum tube development department of Bell Telephone Laboratories, Inc., New York, N. Y., in 1929, where he engaged in the development of gas discharge devices for use in relaying and signaling devices in the communication field. He had become a member of the faculty at the University of Illinois in 1947. He also was a member of the Institute of Radio Engineers and the American Physical Society, and had written a number of articles and held many patents.

MEMBERSHIP . . . .

Recommended for Transfer

The board of examiners at its meeting of May 20, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Brooks, F. E., chief engr., N. Y. Tel. Co., Brooklyn, N. Y.
Coleman, H. C., mgr., marine & avia. sec., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Elzi, J. A., engr., The Commonwealth & Southern Corp., Jackson, Mich.
Farrar, W. B., senior engr., Office, Chief of Engrs., Washington, D. C.
Fifer, W. H., principal elec. engr., Bureau of Ships, Washington, D. C.
Glasgow, R. S., prof. elec. engg; chairman, dept. of elec. engg., Washington Univ., St. Louis, Mo.
Gross, E. T. B., prof. elec. power systems engg., Illinois Inst. of Tech., Chicago, Ill.
Harder, E. L., consulting trans. engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hill, A. W., mgr., circuit breaker engg. dept., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hough, W. R., chief engr., Reliance Elec. & Engg. Co., Cleveland, Ohio.
Kilby, H. S., vice-pres., (operation), Western Light & Tel Co., Inc., Great Bend, Kans.
Lack, F. R., vice-pres., Western Elec. Co., Inc., New York, N. Y.
LaPoe, A. E., central engg. & service mgr., Westinghouse Elec. Corp., Pittsburgh, Pa.
Leeds, W. M., mgr., circuit breaker dev., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Meyerand, R. G., senior elec. engr., Union Elec. Co. of Mo., St. Louis, Mo.
Mikina, S. J., advisory engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Newmeyer, W. L., chief, resources & dev. div., Branch of Power Utilization, Bureau of Reclamation, Washington, D. C.
Oplinger, K. A., advisory engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Read, E. K., mgr., indoor oil cir. bkr. sec., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Sharp, S. M., chief engr., Southwestern Gas & Elec. Co., Shreveport, La.
Shoults, D. R., vice-pres., in chge. of engg., The Glenn L. Martin Co., Baltimore, Md.
Smith, F. V., chief elec. engr., Sargent & Lundy, C. E., Chicago, Ill.
Wallis, C. M., prof. of elec. engg., Univ. of Missouri, Columbia, Mo.

23 to grade of Fellow

To Grade of Member

Anderson, B. T., chief elec. engr., Sundstrand Tool Co., Rockford, Ill.
Anderson, C. A. G., research engr., The Detroit Edison Co., Detroit, Mich.
Baker, A. M., senior layout man, Pennsylvania Elec. Co., Johnstown, Pa.
Burroughs, H. A., assoc. prof.; elec. engg. dept., Michigan College of Mining & Technology, Houghton, Mich.
Caldwell, G. A., mgr. engg. industrial control div., Westinghouse Elec. Corp., Buffalo, N. Y.
Carlson, E. T., pres., The Trumbull Elec. Mfg. Co., Plainville, Conn.
Carter, H. B., div. engr., General Elec. Co., Ft. Wayne, Ind.
Challenner, A., assoc. prof. elec. engg., Univ. of Oklahoma, Norman, Okla.
Chapman, C. H., elec. engr., General Elec. Co., Schenectady, N. Y.
Coons, T., engr. elec. engg. dept., Potomac Elec. Pr. Co., Washington, D. C.
Crane, L. R., Chicago dist. mgr., A. B. Chance Co., Centralia, Mo.
Davis, R. E., asst. product engr., Sperry Gyroscope Co., Great Neck, N. Y.
Dibble, E. S., industrial engr., General Elec. Co., Los Angeles, Calif.
Farrow, C., chief elec. research engr., Republic Steel Corp., Cleveland, Ohio.
Fisher, C. E., member of tech. staff, Bell Tel. Labs., Inc., St. Louis, Mo.
Forman, A. M., elec. engr., Continental Elec. Co. Inc., Rockford, Ill.
Foster, E. M., chief system dispatcher, San Diego Gas & Elec. Co., San Diego, Calif.
Fullerton, D. P., div. mgr., New York Tel. Co., Buffalo, N. Y.
Given, F. J., asst. director trans. App. dev., Bell Tel. Labs., New York, N. Y.
Gogins, J. F., mgr. apparatus dept., General Elec. Co., Portland, Ore.
Hall, C. F., supervisor, product performance analysis sec., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Halter, A. C., elec. engr., Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Hamburger, G., district mgr., St. Louis District, Copperweld Steel Co., St. Louis, Mo.
Haneiko, J. G., electronic control engr., Westinghouse Elec. Corp., Buffalo, N. Y.
Haynes, T. E., elec. operations engr., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Headley, F. B., high-voltage specialty engr., General Elec. Co., Pittsfield, Mass.
Holway, D. K., partner, elec. engr., W. R. Holway & Associates, Tulsa, Okla.
Korsan, W. E., sales engr., Allis-Chalmers Mfg. Co., St. Louis, Mo.
Kuehlthau, J. L., elec. insulation engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
LaHue, P. M., consulting elec. engr., Denver, Colo.
Lieb, J. S., patent attorney, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Linthicum, J. M., genl. engr., The Cheapeake & Potomac Tel. Co., Washington, D. C.
Lodal, O. T., member of firm, Beavers & Lodal, C. E., San Antonio, Tex.
MacIntire, H. L., commercial & industrial rep., Buffalo Niagara Elec. Corp., Buffalo, N. Y.
Martin, M., chge. of elec. dept., Fellheimer & Wagner, New York, N. Y.
Mathews, J. T., asst. mgr., foreign engg. dept., Westinghouse Elec. Corp., East Pittsburgh, Pa.
McBride, R. L., elec. engr., Canadian-Brazilian Services, Ltd., Toronto, Ontario, Canada
McCabe, C. F., elec. engr., Consolidated Vultee Aircraft Corp., San Diego, Calif.
McMillan, A. N., engr., Buffalo Niagara Elec. Corp., Buffalo, N. Y.
McMillan, M. V., supt. of substations, Buffalo Niagara Elec. Corp., Buffalo, N. Y.
Merkle, E. C., installation engr., aeroproducts div., General Motors Corp., Dayton, Ohio.
Moore, A. J., mgr., Providence office, General Elec. Co., Providence, R. I.
Moore, C. E., Jr., engr., Rural Electrification Adm., Washington, D. C.
Mullen, Father Cronan, O.F.M., chairman science div., Siena College, Loudonville, N. Y.
O'Riordan, P. A., elec. design engr., Edward E. Ashley, C.E., New York, N. Y.
Ostman, H. F., system construction engr., Union Elec. Co. of Missouri, St. Louis, Mo.
Purcell, H. C., elec. engr., Sacramento Municipal Utility Dist., Sacramento, Calif.
Ruus, E., engr., The Electric Storage Battery Co., Dallas, Tex.
Satullo, A. R., engg. sales repr., Wayne Univ., Detroit, Mich.
Schwarz, W. E., consulting app. engr., Westinghouse Elec. Corp., St. Louis, Mo.
Shepard, B. R., section engr., General Elec. Co., Schenectady, N. Y.
Smith, H. R., Jr., asst. dept. head, electronics lab., Chrysler Corp., Detroit, Mich.
Steinberg, E. B., project engr., Machlett Labs. Inc., Springdale, Conn.
Stillwell, R. M., local supt., Union Elec. Pr. Co., Alton, Ill.
Trump, J. G., assoc. prof., Mass. Inst. of Tech., Cambridge, Mass.
Wheeler, W. M., engr., General Elec. Co., Schenectady, N. Y.
Wood, D. F., dev. test engr., General Elec. Co., Schenectady, N. Y.

57 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before July 21, 1948, or September 21, 1948, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Allison, R. E., Audio Development Co., Minneapolis, Minn.
Bliven, R. E. Orange & Rockland Elec. Co., Monroe, N. Y.
Byrum, J. F., General Elec. Co., Schenectady, N. Y.
Canada, A. H., General Elec. Co., Schenectady, N. Y.
Church, H. E., Benjamin Elec. Mfg. Co., Des Plaines, Ill.
Corby, R. A., Owens-Corning Fiberglas Corp., Newark, Ohio
Dibble, H. H., General Elec. Co., Schenectady, N. Y.
Eardley, E. P., Dept. of Interior, Washington, D. C.
Emmons, C. D., General Elec. Co., Richland, Wash.
Evans, R. K., California-Pacific Utilities Co., Baker, Oreg.
Gall, H. J., Lower Colorado River Authority, New Braunfels, Tex.
Grover, L. R., East Punjab Public Works Dept., Punjab, Pakistan
Harris, R. H., Westinghouse Elec. International Co., New York, N. Y.
Hinman, J. H., City Utilities, Ft. Wayne, Ind.
Hynes, R. R., Westinghouse Elec. Corp., El Paso, Tex.
Kertz, H. L., Pacific Tel. & Tel. Co., San Francisco, Calif.
Knox, H. T., U. S. Rubber Co., Bristol, R. I.
Lakshminarayanan, B. A. A., Sri Kothandram Mills, Madura, South India
MacMillan, L. C., Dept. of Interior, Washington, D. C.
McGarrity, J. W., Engineer Research & Development Labs., Ft. Belvoir, Va.
Melvill, G. J., Houston Lighting & Power Co., Houston, Tex.
Miller, A., Sanborn Co., Cambridge, Mass.
Milmoe, R., Bechtel Corp., Los Angeles, Calif.
Morgan, W. F. R., Messrs. Baker Perkins Ltd., Peterborough, England
Moulton, C. F., Omaha Public Power District, Omaha, Nebr.

Nuttall, H., Binny & Co., (Madras) Ltd., Madras, India
Oberst, H. J., Natl. Advis. Comm. on Aeronautics, Cleveland, Ohio
Pitts, A. E., General Elec. Co., Richland, Wash.
Reed, F. M., Penna. Elec. Co., Johnstown, Pa.
Rhyneer, S. M., Atomic Energy Comm., Richland, Wash.
Shepherd, C. H., (re-election) General Elec. Co., Richland, Wash.
Slade, L. E., Iowa Power & Light Co., Des Moines, Iowa
Smalley, M. F., The Ohio Power Co., Canton, Ohio
Stanbrook, R. C., Pittsburgh Steamship Co., Cleveland, Ohio
Wood, M. H., Westinghouse Elec. Corp., Baltimore, Md.
Woods, J. E., Central Power & Light Co., Corpus Christi, Tex.

36 to grade of Member

To Grade of Associate

United States, Canada and Mexico

1. North Eastern

Applebaum, S., General Elec. Co., Schenectady, N. Y.
Brown, J. M., General Elec. Co., W. Lynn, Mass.
Caldwell, W. S., Jr., Hubbard, Lawless & Blakely, New Haven, Conn.
Cope, W. C., Taylor Instrument Cos., Rochester, N. Y.
Corwin, N. J., General Elec. Co., Schenectady, N. Y.
Crow, C. R., General Elec. Co., Schenectady, N. Y.
Delehanty, G. J., General Elec. Co., Boston, Mass.
DiLella, P. J., (re-election) General Elec. Co., Schenectady, N. Y.
Goodman, L., The Foxboro Co., Foxboro, Mass.
Graham, J. M., General Elec. Co., Schenectady, N. Y.
Granlund, C. G., General Elec. Co., Schenectady, N. Y.
Gresham, J. C., General Elec. Co., Schenectady, N. Y.
Kimbrell, M. R., Jr., General Elec. Co., Schenectady, N. Y.
Kohler, T. R., Philips Laboratories, Inc., Irvington-on-Hudson, N. Y.
Lanigan, E. D., General Elec. Co., Lynn, Mass.
Maier, J. E., Rochester Gas & Elec., Rochester, N. Y.
Rosenberry, G. M., Jr., General Elec. Co., Schenectady, N. Y.
Peters, J. K., American Tel. & Tel. Co., Albany, N. Y.
Peterson, R. K., General Radio Co., Cambridge, Mass.
Phillips, J. N., General Elec. Co., Schenectady, N. Y.
Ramirez, J. E., Stone & Webster Engg. Corp., Boston, Mass.
Rusk, J. E., General Elec. Co., Schenectady, N. Y.
Seeley, F. P., Trumbull Elec. Mfg. Co., Plainville, Conn.
Shea, C. F., Ward Leonard Elec. Co., Hartford, Conn.
Smith, C. C., General Elec. Co., Schenectady, N. Y.
Soble, A. B., General Elec. Co., Schenectady, N. Y.
Spear, E. D., Cornell Univ., Ithaca, N. Y.
Vail, A. G., General Elec. Co., Schenectady, N. Y.
Walsh, G. W., Univ. of New Hampshire, Durham, N. H.
Weitzel, W. G., Narragansett Elec. Co., Providence, R. I.
Wilson, G., Intl. Business Machines, Endicott, N. Y.

2. Middle Eastern

Bishop, H. D., NACA–FPRL–Cleveland Airport Cleveland, Ohio
Brereton, D. S., General Elec. Co., Philadelphia, Pa.
Brinkman, N. T., Atlantic Refining Co., Philadelphia, Pa.
Browne, H. E., The Ohio Bell Tel. Co., Dayton, Ohio
Casler, H. W., Reese & Bernard Elec. Co., Inc., Johnstown, Pa.
Clothier, J. B., Jr., Villanova College, Villanova, Pa.
Drexler, J., Gem City Elevator Works, Inc., Dayton, Ohio
Drinkhouse, W. H. (re-election) Template Reproduction Co., Philadelphia, Pa.
Dvorak, W. F., Powerlite Switchboard Co., Cleveland, Ohio
Faul, R. G., The Austin Co., Cleveland, Ohio
Fischle, C. F., American Tel. & Tel. Co., Washington, D. C.
Foster, F. A., Cleveland Twist Drill Co., Cleveland, Ohio
Giegel, L. F., Reliance Elec. & Engg. Co., Cleveland, Ohio
Guenveur, J. L., E. E. du Pont de Nemours & Co., Wilmington, Del.
Heycey, S. G., U. S. Dept. of Agriculture, REA, Washington, D. C.
Highley, A. M., Jr., Reliance Elec. & Engg. Co., E. Cleveland, Ohio
Homsher, J. B., Pennsylvania Water & Power Co., Baltimore, Md.
Kilhefner, R. S., F. E. Myer & Bros. Co., Ashland, Ohio
Kraft, D. H., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Kuechle, T. F. (re-election) Central High School, Columbus, Ohio
Kutifoff, M., General Industries, Inc., Philadelphia, Pa.
Lamb, F. S., General Elec. Co., Cleveland, Ohio
Lees, J. R., I. T. E. Circuit Breaker Co., Philadelphia, Pa.
Lundquist, D. C., Westinghouse Elec. Corp., Sharon, Pa.
Macpherson, R. H., General Elec. Co., Philadelphia, Pa.
Marzolf, J. M., Naval Research Lab., Washington, D. C.
Mulcahy, J. V., Bonneville Power Admin., Pittsburgh, Pa.
Peck, D. K., National Elec. Coil Co., Columbus, Ohio
Polinek, C. J., Reliance Elec., Cleveland, Ohio
Sapega, A. E., General Elec. Co., Scranton, Pa.
Scott, F. E., Reliance Elec. & Engg., Cleveland, Ohio
Shell, C. B., Ohio Edison Co., Youngstown, Ohio
Smith, J., Remington Rand, Inc., Washington, D. C.
Steiner, R. R., Natl. Advis. Comm. for Aeronautics Cleveland Airport, Cleveland, Ohio
Taylor, W. S., Crocker Wheeler, Philadelphia, Pa.
Terry, W. M., Jr., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Trbovich, M., Naval Research Lab., Washington, D. C.
Tuck, E., Naval Ordnance Lab., Silver Spring, Md.
Williams, V. P., Central Ohio Light & Power Co., Wooster, Ohio

3. New York City

Doll, E., 6511 Park Avenue, West New York, N. J.
Ellis, F. W., Servo Corp. of America, Lindenhurst, N. Y.
Greer, L. S., Burndy Engg. Co., Bronx, N. Y.
Hograf, E. B., General Elec. Co., New York, N. Y.
Hughes, A. A., 204–12 100 Ave., Hollis 7, N. Y.
Mallalieu, F. R., Dictograph Prods., Inc., Jamaica, N. Y.
Morgenstern, O. A., Servo Corp. of America, Lindehurst, N. Y.
Salley, H. D., Staten Island Edison Corp., Staten Island, N. Y.
Satin, L. R., Joseph Satin Co., Brooklyn, N. Y.
Schleckser, C. E., Jr., Standard Oil Development Co., Elizabeth, N. J.
Wade, O., Sylvania Electric Prod., Inc., Kew Gardens, N. Y.
Wasson, I., 251 5th Ave., New York, N. Y.

4. Southern

Allen, H. A., Southern Bell Tel. & Tel. Co., Greensboro, N. C.
Applegate, J. A., Silas Mason Co., Shreveport, La.
Borgers, R. W., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Buxton, A. C., Tulane Univ., New Orleans, La.
Conger, S. F., Carbide & Carbon Chemical Corp., Oak Ridge, Tenn.
Cunningham, G. W., Atomic Energy Commission, Oak Ridge, Tenn.
Durham, J. C., Jr., Tulane Univ., New Orleans, La.
Gordon, D. D., Robertshaw-Fulton Controls Co., Knoxville, Tenn.
Hatfield, J. N., Knox Porcelain Corp., Knoxville, Tenn.
Levy, I., Natl. Advis. Comm. for Aeronautics, Langley Field, Va.
Mackelfresh, G. S., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
McKeown, T. O., Jr., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Morgan, C., Jr., Southern Bell Tel. & Tel. Co., New Orleans, La.
Rudd, L. L., Jr., Reynolds Metals Co., Richmond, Va.
Saunders, F. B., Duke Power Co., Charlotte, N. C.
Stanton, W. H., Carbide Carbon Chemical Corp., Oak Ridge, Tenn.

5. Great Lakes

Achurra, A., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Belanger, R. N., Michigan College of Mining & Tech., Houghton, Mich.
Crawford, C. E., Midland Elec. Coal Corp., Farmington, Ill.
Fritz, D. G., Illinois Northern Utilities Co., Dixon, Ill.
Gerth, G. O., Otter Tail Power Co., Fergus Falls, Minn.
Hansen, W. R. M., Westinghouse Elec. Corp., Chicago, Ill.
Harrington, B. F., Simplicity Pattern Co., Niles, Mich.
Harris, T. J., Ohio Brass Co., Chicago, Ill.
Harnung, J. M., Caterpillar Tractor Co., Peoria, Ill.
Hoste, J. A., Hoste Brothers, Center Line, Mich.
Johnson, O. H., Western United Gas & Elec. Co., Aurora, Ill.
Kehl, J. H., Benjamin Elec. Mfg. Co., Des Plaines, Ill.
Lasko, W., Caterpillar Tractor Co., Peoria, Ill.
Leimbeck, H. H., Commonwealth Edison Co., Chicago, Ill.
MacDiarmid, E. W., Sr., Pabst Brewing Co, Peoria, Ill.
McNeil, B., (re-election) Laramore & Douglass, Inc., Chicago, Ill.
Paris, G. J., J. Paris & Sons, Detroit, Mich.
Russell, P. E., Univ. of Wisconsin, Madison, Wisc.
Smith, D. H., (re-election), Public Service Co. of Northern Ill., Chicago, Ill.
Spriggs, E. W., Otis Elevator Co., Indianapolis, Ind.
Watkins, D. A., 1608½ Washington Ave., Cedar Rapids, Iowa
Webb, E. M. G., Modern Recording Studio & DeForest's Training, Inc., Chicago, Ill.
Wurtzell, F. W., Bakelite Corp., Chicago, Ill.

6. North Central

Carlson, M. W., Univ. of Denver, Denver, Colo.
DeVoe, S. W., Colorado Pump & Supply Co., Denver, Colo.
Meeker, J. A., c/o School of Mines, Rapid City, S. Dak.
Mueller, M. G., Mark G. Mueller Elec. Apparatus, Denver, Colo.

7. South West

DeLaughter, J. D., Public Service Co. of Okla., Tulsa, Okla.
Dwelle, E. C. (re-election), Jas. R. Kearney Corp., St. Louis, Mo.
Gilcrest, G. R., Missouri Public Service Comm., Jefferson City, Mo.
Godfrey, R. M., Schlumberger Well Surveying Corp., Houston, Tex.
Gohry, H. A., South Western Bell Tel. Co., Dallas, Tex.
Gottfried, H. W. (re-election) 16 de Septiembre No. 10, Despacho 1311, Mexico D.F., Mexico
Gray, R. D., El Paso Elec. Co., El Paso, Tex.
Grenier, L. C., Magnet Cove Barium Corp., Malvern, Ark.
Hawkins, A. T., Union Elec. Co. of Missouri, St. Louis, Mo.
Jauregui, C. J., Abastecedores Generales, S. A., Mexico City, Mexico
Koepsel, W. W., Univ. of Texas, Austin, Tex.
Krause, H. F., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Lewis, H. E., Jr., Shell Chemical Corp., Houston, Tex.
Mashburn, A. G., Gulf States Utilities Co., Beaumont, Tex.
McMillin, E. A., Abilene Elec. Co., Abilene, Tex.
Moore, R. K., Washington Univ., St. Louis, Mo.
Polo, E. M., Comision Federal de Electricidad, Mexico, Mexico
Pritchett, J. D., South Western Bell Tel. Co., Dallas, Tex.
Rodriguez, L. M., Abastecedores Generales, S. A., Mexico City, Mexico
Roettger, R. W., Union Elec. Co., St. Louis, Mo.
Romero, F. A., Industria Elec. de Mexico, Mexico City, Mexico
Schneider, H. W., Jr., 408 North Washington, Stillwater, Okla.
Velazquez, B., J. M., Abastecedores Generales S. A., Mexico City, Mexico
Velkers, G. D., Lt., The Artillery School, Fort Bliss, Tex.
Viniegra J. G., Abastecedores Generales, S. A., Mexico City, Mexico
Zellmer, N. A., Cities Service, Bartlesville, Okla.
Zuniga, M. L., Electronics, S. A., Mexico City, Mexico
Zunzunegui, V. F., Abastecedores Generales S. A., Mexico City, Mexico

8. Pacific

Arnold, W. H., Jr., Central Arizona Light & Power Co., Phoenix, Ariz.
Brand, G. S., Pacific Gas & Elec. Co., San Francisco, Calif.
Bush, A. F., Westinghouse Elec. Corp., San Francisco, Calif.
Cannedy, R. L., Bechtel Corp., Los Angeles, Calif.
Carlson, C. A., Pacific Gas & Elec. Co., San Jose, Calif.
Clark, R. L., Bureau of Power & Light, Los Angeles, Calif.
Craig, A. A., Pacific Gas & Elec. Co., Willows, Calif.
Gillette, W., Dept. of Water & Power, Wilmington, Calif.
Mars, H. L., The Trumbull Elec. Mfg. Co., North Hollywood, Calif.
Meyers, H., Muirson Label Co., Inc., San Jose, Calif.
Mierbach, M. J., 2827 Greenwich St., San Francisco, Calif.
Pattison, L. E., North American Aviation, Inc., Inglewood, Calif.
Pellanda, R. J., San Diego Unified School District, San Diego, Calif.
Piper, B. H., Westinghouse Elec. Corp., Los Angeles, Calif.
Robinson, R. R., Trumbull Elec. Mfg. Co., San Francisco, Calif.
Ruiz, A., Southern California Edison Co., Vernon, Calif.
Sanders, W. M., Arizona Edison Co., Inc., Phoenix, Ariz.
Skiles, A. F., Jr., Stone & Webster Engg. Corp., Gardena, Calif.
Sloan, F. W., California Elec. Works, San Diego, Calif.
Snow, J., Pacific Fire Extinguisher Co., San Francisco, Calif.
Sterling, W. L., Metropolitan High School, Los Angeles, Calif.
Tessier, C. C., Robert F. Biggs Co., Chico, Calif.
Van Osdol, G. W., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Wilts, C. H., California Inst. of Tech., Pasadena, Calif.
Yakahi, S., Bureau of Light, Heat & Power, San Francisco, Calif.
Young, G. O., 128 So. Santa Anita St., San Gabriel, Calif.

9. North West

Adams, O. A., Eugene Water Board, Eugene, Ore.
Anderson, M. A., U. S. Govt. Atomic Energy Comm., Richland, Wash.
Carlen, J. A., General Elec. Co., Richland, Wash.
Francis, F. H., Tacoma Light Div., Tacoma, Wash.
Monteith, O. B., General Elec. Co., Spokane, Wash.
Nelson, M. I., 3400–61 Ave. S. W., Seattle 6, Wash.
Nogle, G. F., Washington Water Power Co., Spokane, Wash.
Peabody, E. P., General Elec. Co., Richland, Wash.
Pierce, L. R. General Elec. Co., Richland, Wash.
Remaly, H. A., General Elec. Co., Richland, Wash.
Scott, E. E., General Elec. Co., Richland, Wash.
Shirley, D. W., Jr., Oregon State College, Corvallis, Ore.
Thorson, W. R., General Elec. Co., Richland, Wash.
Vosmer, L. A., General Elec. Co., Richland, Wash.
Willingham, B. J., General Elec. Co., Richland, Wash.

10. Canada

Johns, W. H., W. L. Stevens, New Westminster, British Columbia, Canada
Mulligan, J. P., Norton Co., Chippawa, Ontario, Canada
Pfaff, W. R., St. Catharines Public Utilities Comm., St. Catharines, Ontario, Canada
Riley, T. M., Candian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
Smith, G. D., Northern Elec. Co. Ltd., Toronto, Ontario, Canada
White, R. M., 219 St. Paul St., West., St. Catharines, Ontario, Canada

Elsewhere

D'Lima, M. J. A., Bombay Elec. Supply & Transport Comm., Fort, Bombay, India
Hudson, F., Overseas Engg. Co., London, England
McCollum, R. E., Creole Petroleum Corp., Maracaibo, Venezuela, S. A.
O'Duffy, P., Electricity Supply Board, Dublin, Eire
Schulhof, A. J. P., Electricity Supply Board, Dublin Eire

Total to grade of Associate
United States, Canada, and Mexico, 200
Elsewhere, 5

OF CURRENT INTEREST

NSRB Study Indicates Danger of Power Shortages for United States

The electric power situation in the United States has been described as tight by Arthur M. Hill, chairman of the National Security Resources Board, in a recent statement summarizing the results of a staff study. The full text of Mr. Hill's statement was as follows:

"There is today practically no slack in the power systems. Spare capacity for possible breakdowns and future load growth is very much lower now than it was during the years preceding Pearl Harbor. Before the war this margin of surplus capacity was in excess of 20 per cent of the peak load. In 1947 the margin was reduced to 5 per cent of the peak. During 1948 and 1949 power generating capacity will not be sufficient to provide really adequate reserves. By 1950 the margins of capability appear adequate in most parts of the country and the situation will be further improved in 1951. The principal exception is the Pacific Northwest region where a progressively greater shortage of power capacity is indicated.

"However, the country should feel greatly reassured by the fact that the electrical utility systems now are engaged in the biggest expansion program in their history. This construction program is firm and orders already have been placed which will take up practically the entire fabricating capacity of the electric equipment manufacturers during 1948 and 1949. This power expansion program involves an increase of roughly 20,000,000 kw—more than twice as much as was planned in 1941 at the start of World War II. However, there is some manufacturing capacity available for the years 1950 and 1951 and we feel that electrical utility systems, heavy power equipment manufacturers, and government agencies concerned should get together to see what can be done to expedite the placement of orders to take advantage of such available manufacturing capacity. This is particularly important in connection with additional hydraulic turbines and water wheel generators that can be delivered in 1950 if orders are placed in the early future. Also, there is some available capacity for the manufacture of the smaller steam turbine generators having a rated capacity of 10,000 kw and less. While present load estimates indicate that a satisfactory balance between power capacity and civilian requirements will be reached by 1951, nevertheless it is clearly desirable to achieve some reasonable margin of excess capacity to provide not only for ordinary civilian requirements but also for the possible future power requirements arising out of an expanded rearmament program. In planning for such additional future power capacity, close attention should be given to economically feasible hydroelectric projects, particularly additional hydro facilities in the Pacific Northwest.

"While we are greatly reassured by the aggressive steps that already have been taken by the electric power systems to remedy the critical power situation, it is clear that any prolonged interruption in the manufacture of electric generating equipment would necessitate governmental action to assure the carrying out of the power program on schedule. If there should be any slippage in the fabrication and erection of these new power plants on schedule, there would be great danger of serious power shortages in many areas of the country with subsequent adverse effects on our entire economy. In short, the present power situation is serious. The National Security Resources Board will work actively with the other government agencies and the industries involved to explore every possibility of expediting and enlarging the power program. We also shall keep in touch with developments so that we can recommend such governmental action as may be required in the light of future contingencies."

Mr. Hill's statement was based upon studies of the capacity and requirements of power systems and of the status of the production of heavy power equipment recently undertaken by two advisory committees as a result of a meeting on April 5 held by Mr. Hill with electrical utilities leaders and government representatives.

The studies were made under the immediate direction of Edward Falck (A'40) chief consultant of the board on power and utilities, and Consultant Paul B. Valle.

If the electric power expansion program proceeds according to schedule, the studies disclosed, an increase of roughly 20,000,000 kw of capacity will be provided by the end of 1951.

The studies pointed out, however, the desirability of government encouragement both in seeing that manufacturers of generating equipment obtain the necessary materials to carry the expansion program to completion but, also, to assure that timely orders are placed to take advantage of available manufacturing capacity now indicated in 1950 and 1951.

The committee which made the study on capacity and requirements of power systems included V. M. Marquis (M'31) American Gas and Electric Service Corporation, New York, N. Y., and J. E. Moore (A'12) Ebasco Services, Inc., New York, N. Y.

The committee which studied the status of production of heavy electric power equipment included Walker L. Cisler (M'35) The Detroit Edison Company, Detroit, Mich.; Donald C. Luce (M'36) Public Service Electric and Gas Company Newark, N. J.; Chandler W. Jones (M'44) The New England Electric Systems, Boston, Mass.; and Mark Eldredge (F'33) Munitions Board, Washington, D. C.

Westinghouse Official Cites Need for Engineer-Executives

One of the biggest needs in industry today is for more engineers qualified to accept industry's executive positions, and to fill this need a joint effort on the part of the individual engineer, the college, and industry is necessary if more engineers are to accept executive as well as traditional responsibilities according to Walter Evans, vice-president of the Westinghouse Electric Corporation, East Pittsburgh, Pa.

Mr. Evans was the speaker at a dinner meeting of the Johns Hopkins Chapter of the Tau Beta Pi following initiation ceremonies during which he was elected an honorary member of the society.

Pointing out that the demand for the engineer in administrative positions resulted from the complex new problems which mass production introduced to industry, Mr. Evans advocated a 3-point program to prepare the engineer for his new responsibilities. He proposed that "colleges and universities liberalize curricula to include more cultural courses; that industry provide specialized training for the graduate engineer; and that the individual engineer realign his sights and broaden his own personality and interests" to meet this new challenge. He explained that the engineer joined the banker and the lawyer in top managerial posts when mass production created technical problems which only the engineer could solve. A new trend started when it was discovered that an engineer's training—an orderly scientific approach to a given problem—gave the engineer a sound foundation for managerial responsibilities.

This trend, according to Mr. Evans, is shown clearly by an independent survey published within the last year which shows that one-third of the largest corporations in America—50 out of 150—are headed by graduate engineers. But it is significant, that in each instance where an engineer has met with success as an executive, he has had to expand his training and knowledge to include the broad principles of business. If this trend, one which has helped bring American industry to a new high-water mark in quality and quantity production, is to continue, the engineer must be provided with new tools to do the new job.

Emphasizing that the present educational system does a fine job of training research men, teachers, and engineers for advance development, Mr. Evans said that for the average engineer in industry, colleges and universities can make even more valuable contributions if they will re-examine existing courses and realign subjects to meet the expanding needs of the engineer.

Turning to industry, the speaker pointed out that it has a responsibility to provide the specialization which the engineering graduate does not receive if he has been trained under a broad-gauge educational program. Many industries prefer to prepare engineers under a student training program even though they realize it will take the graduate a year or two before "he earns his salt." They know it

will take them that long to get the "feel" of the business; to learn to find things; and, most of all, to begin to absorb some of the experience of their older associates.

Giving the graduate engineer an opportunity to inspect many different types of engineering jobs will make it possible for him to select one that interests him; he will do a better job, and he will be happier while he is doing it. Then too, since in his training period he sees what other departments are doing, he is aware of their problems and can offer better co-operation.

But even more important, the high degree of specialization in industry today frequently nullifies the effect of academic specialization. Because there are so many varying factors, most graduates are understandably unable to decide what industry they want to work in, to say nothing of what particular phase will attract them. Furthermore, almost any industry you can name is developing so fast that much of the up-to-the-minute information is available only in the industry itself.

As for the individual, colleges and industry must unite to give him "a new set of standards," Mr. Evans said, pointing out that "the miracles of modern living are a tribute to yesterday's engineer—the man who was asked only to create them. If we can show that an engineer can provide even greater service in the future by expanding his activities beyond the pure engineering field, I feel sure that the student of today will accept the challenge and meet it as successfully as did his academic forebearers."

Army Affiliation Program Seeks Engineer Reserve Units

Nearly half of the engineer units required by the United States Army in its organized reserve program are being established under the "affiliation program" launched in May 1947 by Secretary of War Patterson. The affiliation program is an integral part of the organized reserve program. Affiliated units are sponsored by civilian organizations performing functions closely allied to the units' projected military assignments; their key personnel normally are drawn from the employees of the sponsoring organization, with civilian occupational skills paralleling needed military specialties. The concept of building engineer units around nuclei of trained technicians who have worked together as teams in comparable civilian jobs is a sound one. Reserve units so constituted quickly can be brought to full effectiveness because the technical know-how, which requires much longer to instill than military efficiency, already is developed.

Chief interest of electrical engineers naturally centers around the reserve activities of the Corps of Engineers, whose program comprises engineer units ranging from the large engineer construction groups through the smaller, highly specialized engineer power plant operating detachments.

In implementing its portion of the program the Corps of Engineers is signing general contractors to sponsorship agreements for construction, port construction and repair, and airfield construction battalions. Municipal fire departments are sponsoring firefighting platoons; municipalities and labor locals are sponsoring utilities detachments; equipment distributors have engineer depot and maintenance companies and engineer parts supply platoons; and manufacturers have heavy shop companies and foundry detachments. Agreements for more than 300 such engineer reserve affiliated units already have been signed by civilian organizations of industry, labor, and federal, state, and municipal governments. A number of these units already have been activated and are being organized.

The agreements, signed jointly by representatives of the sponsoring agency and the Department of the Army, are "mutual expressions of good faith, active interest, and confidence only." They may be terminated by either party on written notice. The sponsor provides key personnel from his own organization and undertakes to keep his unit at prescribed strength with qualified men. Everyone in the reserve affiliated unit need not necessarily be an employee of the sponsoring agency.

The unit commanding officer selected must be mutually acceptable to the sponsor and the Department of the Army. All unit officers must hold reserve commissions, and all enlisted men must be members of the Organized Reserve Corps. Once the unit is activated, its commanding officer, supervised and assisted by regular Army reserve instructors, is responsible for administration and training—the sponsor being required to do little more than provide moral support and maintain interest in keeping the unit at strength.

The extent of training to be conducted by each unit is incorporated in the original sponsorship agreement; it may vary from weekly armory-type periods, plus 15 days of field training annually, to quarterly training with no summer field training. Monthly or quarterly periods are permitted where the civilian occupations of the personnel involved so closely are allied to the units' military assignment that further training in the primary mission is not essential. These periodic armory-type training sessions are the ones for which compensation has been authorized by recent legislation. The organized reserves who heretofore have attended the regularly scheduled evening or weekend sessions without compensation will receive one day's pay for the 2-hour armory-type sessions as soon as funds are allocated and enabling regulations by the Department of The Army are published.

The affiliation program creates units which can accomplish maximum utilization of our valuable resource of individual technical skills. For the reservist with specialized training, it offers him an opportunity to assure for himself an assignment of his own choosing in event of a war emergency. By joining the proper affiliated organization, anyone with technical know-how vital to the functioning of a specialized unit helps solve in advance the huge classification task confronting a mobilization effort by "preclassifying" himself, so to speak, to the mutual benefit of both the defense effort and his own morale.

Negotiations with potential sponsors of engineer reserve units are being conducted by the various district engineer offices, which are the best sources of information regarding the units being formed or to be formed in a particular locality. Senior instructors of the various military districts should be contacted, however, on matters of individual status and assignment in the Organized Reserve Corps.

Connecticut Technical Council Endorses Conservation Program

Early this year the Connecticut Technical Council voted to support a program advocating conservation of the natural resources of the United States. Since that time, letters have been written to practically every technical council and engineering society in the United States calling attention to the program and soliciting supporting action. It is the belief of the council that, by putting their weight behind the project, American engineers can bring about a clearer realization on the part of Congress and the administrative branch of the government of the value and necessity of the conservation of our natural resources as well as avoidance of a third world war. The points set forth in the council's program include:

1. Urgently recommending action on the part of those in the government to the end that as far as possible

Future Meetings of Other Societies

American Oil Chemist's Society. Fall meeting, November 15–17, 1948, Pennsylvania Hotel, New York, N. Y.

American Radio Relay League (ARRL) Convention. September 4–6, 1948, Milwaukee Auditorium, Milwaukee, Wis.

American Society of Civil Engineers. Summer convention, July 21–23, 1948, Seattle, Wash.; fall meeting, October 13–15, 1948, Boston, Mass.

Association of Iron and Steel Engineers. Iron and Steel Exposition, September 28–October 1, 1948, Cleveland, Ohio.

Conference on Research Administration. September 13–15, 1948, Pennsylvania State College, State College, Pa.

First Annual All-Electrical Exposition. August 20–29, 1948, Pan Pacific Auditorium, Los Angeles, Calif.

FM Association. Annual convention, October 11–12, 1948, Sheraton Hotel, Chicago, Ill.

Illuminating Engineering Society. National technical conference, September 20–24, 1948, Boston, Mass.

Institute of Radio Engineers. Pacific Coast convention, September 30–October 2, 1948, Los Angeles, Calif.

Instrument Society of America. Third instrument conference and exhibit, September 13–17, 1948, Philadelphia, Pa.

National Electrical Manufacturers Association. November 8–13, 1948, Atlantic City, N. J.

National Electronics Conference. November 4–6, 1948, Edgewater Beach Hotel, Chicago, Ill.

National Exposition of Power and Mechanical Engineering. November 29–December 4, 1948, Grand Central Palace, New York, N. Y.

National Plastic Exposition. September 27–October 2, 1948, Grand Central Palace, New York, N. Y.

National Research Council's Conference on Electrical Insulation. October 27–29, 1948, at the National Bureau of Standards, Washington, D. C.

National Television and Electrical Living Show. September 18–26, 1948, Chicago Coliseum, Chicago, Ill.

Porcelain Enamel Institute. Tenth annual forum, October 13–15, 1948, Urbana, Ill.

all foreign aid be in the form of loans and that payment be in raw materials, object being to save the dignity and self-respect of the recipients as well as to bolster up our dwindling stock piles of vital minerals and other resources.

(a). Doing all possible to bring about world government so as to avoid a third world war that would not only use up all of our natural resources, but would wreck our civilization as well.

2. Calling upon The American Manufacturers Association to institute scrap drives throughout the nation and our military branches of the nation to issue orders to their respective commands, to the effect that vital materials, first of all, are to be used carefully, and second, that all scrap be saved. Money can be printed and turned out of the mint in rather a short time, but it will take centuries to replenish nature's storehouses.

3. Imploring each individual engineer and metallurgist to do his bit by using the very best methods and highest efficiency in mining, smelting, and refining of minerals, chemicals, coal, and petroleum and our forest products.

4. Lending our strength to the support and passage of legislation that will prevent the shipment of our vitally needed scrap and other materials to nations of doubtful friendliness.

5. Advocating and supporting legislation and its enforcement that calls for protection of our forests and agricultural land. The Department of the Interior is doing a commendable piece of work.

6. Supporting the very best possible public health program, for without a healthy populace our nation cannot develop its resources or protect itself.

7. There are approximately 247,000 engineers in the United States. They can be a real force in prolonging and strengthening the life of our republic.

Much can be accomplished by writing firm, courteous, suggestive letters to members of Congress. We all realize education and culture of humans is a slow everlasting battle. Don't give up the fight. Our representatives are busy people and only pay attention to persistent effort on the part of their constituents.

8. Talking directly and strongly to those who would interfere with our continuance as a republic, and our present way of living.

At the recent AIEE North Eastern District meeting (New Haven, Conn., April 28–30, 1948), T. J. Russell, chairman of the Connecticut Technical Council, spoke on "Conservation of Our Natural Resources" pointing out the seriousness of the present status of our natural resources. His remarks in this regard appear elsewhere in this issue (*pp 623–4*).

Second Applied Mathematics Symposium to Be Held at MIT

The second annual symposium on applied mathematics will be held at Massachusetts Institute of Technology, Cambridge, Mass., July 29–31, 1948. Subject of the symposium will be electromagnetic theory. The meeting is being held under the auspices of the American Mathematical Society, and the AIEE basic sciences committee is acting as cosponsor. The symposium is under the direction of Professor W. T. Martin, head of the mathematics department at Massachussets Institute of Technology.

An interesting program of 19 papers including 13 20-minute and 6 40-minute addresses will be presented by prominent mathematicians, engineers, and scientists from the United States and Canada, including an address by a mathematician from the University of Palestine. The program has been arranged to leave ample time for discussion, and it is hoped that there will be full participation of engineers and scientists as well as mathematicians during the discussion periods.

The symposium is an extension of the series of conferences which the AIEE subcommittee on applied mathematics of the AIEE basic sciences committee has been conducting at recent technical meetings of the AIEE. The following is a list of the subjects to be presented during the program. The 20-minute addresses include:

"Nonlinear Electrical Networks," Professor R. J. Duffin, Carnegie Institute of Technology, Pittsburgh, Pa.

"Generalization of the Schroedinger Perturbation Theory," Professor Eugene Seenberg, Washington University, Seattle, Wash.

"Systems of Simultaneous Wiener-Hopf Integral Equations and Their Application to Some Boundary Value Problems in Electromagnetic Theory," Professor Albert E. Heins, Carnegie Institute of Technology, Pittsburgh, Pa.

"Asymptotic Development of Steady Solutions of Maxwell's Equations Based Upon Discontinuities of Pulsed Solutions," Professor R. K. Luneberg, New York University, New York, N. Y.

"The Statistical Theory of Message Transmission," Professor W. Y. Lee, Massachusetts Institute of Technology, Cambridge, Mass.

"Ray Theory Versus Normal Mode Theory in the Propagation of Electromagnetic or Acoustic Radiation," Professor C. L. Pekeris, Wiseman Institute, Palestine University, Israel.

"Aberration Correction with Selectron Mirrors," Doctor E. G. Ramberg, Radio Corporation of America, Camden, N. J.

"Theory of the Transmission of Information," Doctor C. E. Shannon, Bell Telephone Laboratories, New York, N. Y.

"Wave Propagation in Electromagnetic Horns," Professor A. F. Stevenson, University of Toronto, Toronto, Ontario, Canada.

"Orbits of Charged Particles," Professor A. H. Taub, Institute for Advanced Studies, Princeton University, Princeton, N. J.

"Problems Related to Measuring the Field Strength of High-Frequency Electromagnetic Fields," Professor John Truell, Brown University, Providence, R. I.

"Transient Response and the Central Limit Theorem of Probability," Professor Henry Wallman, Massachusetts Institute of Technology, Cambridge, Mass.

"Discontinuity in Electromagnetism," Doctor W. H. Watson, Canadian National Research Council, Ottawa, Ontario, Canada.

The following is a list of the 40-minute addresses:

"The New Quantum Electrodynamics," Professor Herrman Feshbach, Massachusetts Institute of Technology, Cambridge, Mass.

"Distribution Problem in the Theory of Random Noise," Professor Marc Kac, Cornell University, Ithaca, N. Y

"Reflections from Bends and Corners in Electromagnetic Wave Guides," S. O. Rice, Bell Telephone Laboratories, New York, N. Y.

"Electromagnetism Without Metric," Professor J. L. Synge, Carnegie Institute of Technology, Pittsburgh, Pa.

"Entropy Information," Professor Norbert Weiner, Massachusetts Institute of Technology, Cambridge, Mass.

"The Factorization Method and Its Application to Differential Equations in Theoretical Physics," Professor Leopold Infeld, University of Toronto, Toronto, Ontario, Canada.

Technical Translation Index Service Established

Translating costs for many scientific and technical articles and reports in foreign journals now can be eliminated by the use of a new "union card index of technical translations" compiled and serviced free of charge by the science-technology group of the Special Libraries Association.

A master card file records known translations into English from foreign language articles or reports in the fields of engineering, materials, aeronautics, chemistry, metallurgy, communications, petroleum, and technology. Among those who have contributed data on translations in their files are many private industrial firms and such well-known agencies as the American Documentation Institute, David Taylor Model Basin, Office of Technical Services, Ministry of Supply (R.T.P.), the Iron and Steel Institute, and many others.

Any organization or institution engaged in research in these fields is invited to co-operate

Engineering Students Visit Lamp Division

D. D. Knowles (M '39) manager of electronic tube engineering, third from left, explains the operation of a modern electron tube to a group of senior electrical engineering students from the University of Michigan on a visit to the Westinghouse Electric Corporation's lamp division plant in Bloomfield, N. J., during a week-long field trip sponsored by the AIEE Student Branch at the University of Michigan and Eta Kappa Nu

by sending a record of its translations to the index, or by inquiring for information on the availability anywhere in the United States of a translation of a needed article. The index service does not supply the translations, but acts as a clearing house to supply to the inquirer the name of the organization or agency which already has a translation. The requester then makes arrangements directly with the holder of the translation for the loan or purchase of a copy.

To provide for organizations not wishing to reveal their interests through disclosing translations in their files, however, the service will act as exchange intermediary for the loan, keeping the firm names anonymous. Contributions of index cards and use of the service are invited from any interested organizations. All inquiries should be addressed to Mrs. Miram Lamduyt, Research Librarian, Caterpillar Tractor Company, Peoria 8, Ill., who is chairman of the Translation Index Service for the science-technology group of the Special Libraries Association.

Television Tube Output Speeded by Robot Machine

Manufacture of 10-inch cathode-ray television picture tubes, already on a mass-production basis at the Lancaster, Pa., plant of the tube department of the Radio Corporaation of America, further has been stepped up and mechanized by the installation of the first of three giant "settling machines" as part of the conveyer-belt system stretching over the 7-acre plant.

The new endless-belt machine which handles 144 glass bulbs at a time, carried along in three parallel lines, is the critical point at which the luminescent face is applied to the cathode-ray tube. The process, which previously was performed by hand on each individual bulb and entailed numerous operations and delays between steps, now has been converted into a totally automatic process with a single girl operator loading and unloading the machine. Rate of production of the new machine, which has reduced spoilage to a minimum by eliminating human handling, is better than one a minute.

Resembling a huge treadmill, the new machine automatically dispenses precise quantities of a solution containing luminescent materials into the glass bulbs and carries them along a 33-foot vibration free traverse while the luminescent coating settles evenly over the tube face.

The excess fluid then precisely is poured off as the bulbs tip over the end of the machine moving at the barely perceptible speed of $3^1/_2$ inches per minute, the necks are washed first in an acid then a water bath, and the coating finally dried by forced warm air—all automatically.

The precise engineering in every step of the process is illustrated by a newly devised "robot" dispenser on the machine. Instead of simply pouring the luminescent-materials solution directly into the bulb, which might cause the solution to settle unevenly on the glass bulb face, the dispenser first pours a 1-inch deep cushion of double-distilled water into each bulb and then sprays the luminescent-materials solution over the entire surface of this water cushion to insure even settling at all points.

To eliminate vibration which might agitate the solution during the exacting settling process, the huge $3^1/_2$-ton machine is finely balanced on precision ball bearings and is propelled by a single one-fourth-horsepower electric motor. In addition, the entire machine stands on an "island" isolated from the rest of the plant by thick alternate layers of cork and concrete to prevent external vibrations from disturbing the process.

Southwark Station Dedicated. Philadelphia Electric Company's newest addition to its electric generating system, the $45,000,000 Southwark station, was dedicated on May 7, 1948. Located on the Delaware River, in southeast Philadelphia, Southwark's presently-installed two generating units have an aggregate capacity of 338,000 kw. The plant is designed to permit the use of either coal or oil to develop steam to drive the generators. Using coal only, 3,700 tons are consumed daily to produce a required 3,600,000 pounds of steam an hour. Southwark is the company's fifth major steam generating station to be located on the Delaware River, where access to water in unlimited supply, and to coal, by both rail and barge, are important considerations. Some 450,000,000 gallons of water a day are circulated through condensers during the operation of the plant's turbogenerating units. It then is returned to its river source. The seven major steam generating stations of the company, plus its highly-important Conowingo hydroelectric plant on the Susquehanna River, serve more than 850,000 customers and a population of more than 3,000,000 people in a service area of 2,255 square miles. Philadelphia Electric Company and neighboring utilities are interconnected in a power pool of more than four million kilowatts. This pool is tied in with a similar "grid system" of six million kilowatts in New York State and New England, and with a third power pool of $1^1/_2$ million kilowatts in the Baltimore-Washington area.

Scientists Receive Awards for Services to Armed Forces

The award of the Medal for Merit to 65 scientists and engineers of the wartime Office of Scientific Research and Development in recognition of their outstanding service to the Armed Forces was announced recently by Secretary of Defense James Forrestal.

Doctor Vannevar Bush (F '24) who was director of the OSRD during the war, and now is chairman of the Research and Development Board, National Military Establishment, as well as president of the Carnegie Institution of Washington, D. C., presented seven of the decorations in a special ceremony at the Pentagon on May 21, 1948. Among those decorated at this ceremony was Doctor Alan Tower Waterman (M '48) Office of Naval Research, Washington, D. C.

Also included in the list of recipients of the Medal for Merit are the following AIEE members:

Doctor Edward Lindley Bowles (F '33) Wellesley Farms, Mass.

Doctor Samuel Hawks Caldwell (A '27) Massachusetts Institute of Technology, Cambridge, Mass.

Melville Eastham (F '46) General Radio Company, Cambridge, Mass.

Doctor Lars Olai Grondahl (F '47) Union Switch and Signal Company, Pittsburgh, Pa.

Doctor Herbert Eugene Ives (F '29) Bell Telephone Laboratories, New York, N. Y.

Doctor Zay Jeffries (F '42) General Electric Company, Pittsfield, Mass.

Edward Leyburn Moreland (F '21) Massachusetts Institute of Technology, Cambridge, Mass.

Doctor Brian O'Brien (F '47) University of Rochester, Rochester, N. Y.

Harold Bours Richmond (F '40) General Radio Company, Cambridge, Mass.

Hartley Rowe (F '48) United Fruit Company, Boston, Mass.

Doctor Chauncey Guy Suits (F '47) General Electric Company, Schenectady, N. Y.

Doctor Frederick Emmons Terman (F '45) Leland Stanford University, Stanford University, Calif.

Electrical Engineering Fellowships. The graduate college of the University of Illinois, Urbana, Ill., recently announced the following fellowship appointments in electrical engineering for the academic year starting September 1, 1948.

E. I. Du Pont de Nemours Fellowship: Clarence E. Bergman (bachelor of science, University of Oklahoma, 1947; master of science, University of Illinois, 1948).

Galvin Fellowship (Motorola, Inc.): Kenneth A. McCollom (bachelor of science, Oklahoma Agricultural and Mechanical College, 1948).

Jansky and Bailey Fellowship: Israel A. Lesk (bachelor of science, University of Alberta, 1948).

Westinghouse Educational Foundation Fellowship: John H. Bryant (A '46, bachleor of science, Agricultural and Mechanical College of Texas, 1942; master of science, University of Illinois, 1947).

University of Illinois Fellowships: S. K. Ghandhi (bachelor of science, Benares Hindu University, 1947); Chi-Yung Lin (bachelor of science, National Central University, 1942; master of science, Oregon State College, 1948).

University of Illinois Scholarships: Robert A. Dingwall (bachelor of science, University of Alberta, 1948); James S. S. Kerr (bachelor of arts, University of British Columbia, 1948); Lionel Shub (bachelor of science, Illinois Institute of Technology, 1948).

These fellowships and scholarships carry exemption from fees and no services by the student are required by the department of electrical engineering.

Technical Societies Council of New York Elects Officers

On May 20, 1948, the Technical Societies Council of New York held its annual meeting and election of officers. The council was incorporated just a year ago, with local groups of 14 leading engineering societies, representing some 25,000 engineers in the metropolitan area, as charter members. Each society has two delegates to the council, which serves as a medium for mutual professional betterment, more effective public service, the furtherance of high professional standards, and the advancement of engineering and scientific knowledge.

Officers elected were:

President—C. S. Purnell (M '35) of the AIEE, in charge of the petroleum section, industry department, Westinghouse Electric Corporation, New York, N. Y.

Vice-President—O. B. J. Fraser of the American Institute of Mining and Metallurgical Engineers, assistant manager of the development and research division, International Nickel Company, New York, N. Y.

Secretary—Doctor W. F. O'Connor of the American Chemical Society, associate professor of chemistry at Fordham University, New York, N. Y.

Treasurer—Professor M. C. Ciannini of the American Society of Heating and Ventilating Engineers, associate professor of air conditioning at New York University, New York, N. Y.

This is "Intelex," an automatic electric machine used to store reservations information for organizations such as air lines, railroads, and bus lines

The council also elected five new directors. The officers of the council and its directors, six in number, constitute its governing board.

Civil Service Announces Naval Command Positions

Applications are being accepted by the Executive Secretary, Board of United States Civil Service Examiners for Scientific and Technical Personnel of the Potomac River Naval Command, Building 37, Naval Research Laboratory, Washington 20, D. C., for chemist, engineer, physicist, mathematician, and metallurgist positions.

Salaries range from $3,397 to $5,902 a year. No written test is required. To qualify, applicants must have had college study or technical experience or a combination of such study and experience, plus professional experience in the appropriate field. Graduate study may be substituted for part of the experience. Detailed information about requirements for each position is given in the examination announcement.

Information and application forms may be secured at most first- and second-class post offices, from Civil Service regional offices, or from the United States Civil Service Commission, Washington 25, D. C. Applications will be accepted until further notice by the executive secretary of the board of examiners at the foregoing address

IT &T Engineers Develop Robot Reservations Clerk

An electrically operated machine known as "Intelex" which can make reservations automatically for air lines, railroads, bus lines, steamship lines, hotels, and theaters has been developed by engineers of the International Telephone and Telegraph Corporation, New York, N. Y.

Messages received by this equipment on a teleprinter circuit from, say, a district air line office are analyzed and an answer is sent back to the point of origin automatically. If the space is available the information is stored by the machine and the reply is sent back accordingly. If not then the clerk is informed of the next available space, but this space is not recorded as sold until the clerk indicates the desire for confirmation in a subsequent message. It is also possible for any person in the system to learn from the machine the number of seats sold or available on any leg of any flight at any time.

Provision also is included in the Intelex for a "broadcast circuit" to warn all stations periodically and automatically that certain flights have been sold out, or that they rapidly are approaching that condition.

Electric Motor Manufacturers Mark 40 Years' Association

Forty years of electric motor industry contribution to better living and industrial efficiency was celebrated by the motor and generator section of the National Electrical Manufacturers Association at The Homestead, Hot Springs, Va., on Tuesday evening, June 1, 1948.

The occasion was the 40th anniversary of a 1908 meeting of electric motor manufacturers at the same place, which resulted in the formation of the American Association of Electric Motor Manufacturers, first trade association in the electric apparatus manufacturing industry, and earliest predecessor of NEMA.

Several of the original group were present, two of whom, R. J. Russell, vice-president and secretary of the Century Electric Company, and Clarence L. Collens (M '40) chairman of the board of The Reliance Electric and Engineering Company, and a member of the NEMA board of governors, are still active in the industry and in NEMA. Mr. Russell was one of the original vice-presidents of the old association.

Among the founders present, in addition to Mr. Russell and Mr. Collens, was F. S. Hunting (F '13) who represented the Fort Wayne Electric Works in 1908 and later was with the General Electric Company and then chairman of the board of directors of Robbins and Myers. Other survivors of the original group include S. L. Nicholson (F '13) Westinghouse Electric Corporation, W. A. Layman (F '12) and A. H. Timmerman (F '12) Wagner Electric Manufacturing Company.

George C. Tenney (M '42) vice-president of the McGraw-Hill Publishing Company, acting editor, *Electrical World*, and editor and publisher, *Electrical West*, was the principal speaker.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

American Engineering Association

To the Editor:

For nearly 25 years the civil, mining, mechanical, and electrical engineers, and more recently, the chemical engineers, have been talking and writing about the need for professional recognition and representation. Everyone is in agreement that there should be some one over-all agency qualified to speak with an authoritative voice for "we engineers." Many plans have been brought forth for discussion, some of which have had merit, some of which have had none, but there has been one point which has been a common meeting ground for all proposals. Every speaker, every writer, and every committee which has studied the problems of the professional requirements of the engineer has come to the conclusion that there must be one central agency to assume the responsibility of directing the professional, economic, and social program of the engineering profession, and that this central agency must have the support of the entire engineering profession so that it will speak with the voice of authority.

After reaching this conclusion, the similarity between the individual studies comes to to an abrupt parting of the ways. No two studies agree upon what is the proper method of setting up this over-all agency, nor do the various plans show much evidence of co-ordination with one another.

Blake D. Hull, as president of AIEE, advocated the organization of an American Engineering Association based on the report of the Institute's professional activities subcommittee published in the May 1947 issue of *ELECTRICAL ENGINEERING* (*pp 496–500*). Mr. Hull's article (*EE, Apr '48, pp 313–17*) reviews briefly some of the past efforts towards professional development and its problems, and concludes with a discussion of the organization required to create such an association. Mr. Hull obviously agrees that our Founder Societies are not equipped to function effectively outside of their technical fields, either individually or collectively. He points out that the Engineers Joint Council, made up of civil, mechanical, mining, electrical, and chemical society representatives, cannot speak for all engineers because it is not representative of all engineers, even if its membership were made up of individual members of these societies and if its authority were broadened.

The solution, Mr. Hull says, is to create a new organization which will not interfere with the technical activities of the individual societies, and which will concern itself solely with the professional aspects of engineers. The AIEE and the other technical groups will surrender all of their efforts in the professional field to this new organization, and will devote their efforts entirely to the dissemination of technical information.

There is one very vital question which arises and which Mr. Hull has not mentioned. Who will make up the rank and file of membership in this new association? The inference is that it will be made up of all engineers—but who is an engineer and who is not an engineer? If EJC is not representative of engineers, what or who will be? We know that there are many men who are represented by AIEE who are not electrical engineers. For example, the April 1948 issue of *ELECTRICAL ENGINEERING* (*pp 408–13*) lists 11 members who are up for transfer to the grade of Fellow, 25 who are applying for transfer to the grade of Member, and 46 who are new applicants for the grade of Member. It is probably safe to assume that all of these men are bona fide engineers—as it is practically impossible to attain these grades of membership in the Institute without giving ample evidence of being qualified for such grade. However, there are 1,063 applications for the grade of Associate. How many of this group are really engineers? How many are college graduates of a year or two past, and are junior engineers, or engineers-in-training? How many are draftsmen? How many are salesmen?

At this point another question arises. What is the fine line of demarcation between the junior engineer, or the engineer-in-training, and the engineer? At what point does the transition occur? How are we to determine these things? After all, if we are to have an organization which will speak for all engineers, we first must have an organization that represents all engineers—and engineers *only*. We certainly cannot look to the lower grades of membership in the technical societies as a bona-fide source of enginers when so many of them are not engineers and never will be. We must have some fundamental standards by which to judge a man's right to the title engineer, and such a professional association must be made up of members who are qualified by these standards.

The National Society of Professional Engineers has taken the stand that the only yard stick we have for determining a man's qualifications is his state registration. NSPE takes the attitude that if the laws of the state in which a man practices recognize him as an engineer, there can be no question of his qualification. Every state in the union now has a registration law, and every law defines a professional engineer. Unfortunately, the registration laws do not require that every engineer be registered, but it should be to the interest of every engineer to do so in any event, for the accepted standard of a man's professional ability is his registration.

Does not the NSPE's definition of a professional engineer stand up under close scrutiny as the only logical way of defining an engineer? If the state examines a man, finds him qualified, and certifies him by registration, we have a legal basis for giving him recognition as an engineer, a man of professional standing on the same plane that a medical man or lawyer is qualified as a professional man.

Now let us examine the program of the NSPE. Every point that Mr. Hull is looking for is covered by the NSPE program. NSPE concerns itself solely with the professional, economic, and social problems of the engineer. It was organized in 1934, a mere 18 years ago, for the sole purpose of handling the professional problems of engineers; and in these 18 years it has grown to a society of nearly 18,000 members, and is continuing to grow at an amazingly rapid rate. Remember that the requisite for membership is registration, and then stop and consider just what this means in terms of a representative group. It means that it is a cross section of the profession, an organization that is qualified to speak authoritatively for professional men. It is composed of local chapters which are part of the state society, which, in turn, is part of the national society. The individual member has a direct voice at the national level.

Is this not the American Engineering Association for which Mr. Hull is campaigning? Does it not fulfill all of Mr. Hull's specifications?

Why should the Institute advocate the organization of a new association which will duplicate the efforts of a society that has been building for 18 years? It would seem much more logical to urge the registration of our AIEE members, and to support the program of the NSPE. Active support of the Founder Societies will give NSPE the added membership it will require to take its place in the engineering field as the voice of the engineer—the voice which will say "we engineers" with the ring of authority so desperately needed within our profession.

A. D. SPICER (M '47)
(Kewanee Boiler Corporation, Kewanee, Ill.)

To the Editor:

Suggest what we need is *not* another association—we have too many now. We need a set of standards for engineers—hours of work, rates of pay, vacation time, leave of absence for technical convention attendance, and so forth.

These standards could be formulated by one of the present standardizing agencies such as American Standards Association or even the Underwriters' Laboratories, Inc. (preventing the burning fire of dissatisfaction would be right down their alley!) Expenses for the study and formulation of the standards of working conditions would be shared by the present engineering organizations.

The set of standard working conditions would be endorsed by the various engineering groups in much the same manner that we sanction standards of measurement, control, and the like. The tolerances could be wide at first so as not to be too disturbing and then gradually, as we knew more of what was right and fair, they would be tightened.

Both the engineer and his employer want to do what is right and fair but it is surprising how little we know and understand about the simple facts like rates of pay. A clearly presented recognized standard is what is required and not more empty print full organizations.

FRED LINGEL (M '46)
(Electrical engineer, Triplett Electrical Instrument Company, Bluffton, Ohio)

To the Editor:

This letter is in brief comment on President Hull's article in the April issue regarding the organization of a national association of engineers. I believe that the basic idea is sound and the organization of such an association should be begun immediately. We should keep one thing straight, however. Mere membership in a professional society does not automatically make for prestige, and I include the American Medical Association and the American Bar Association in this. Too often an engineer sighs and remarks that if only there were an engineering society like the one the doctors have, our troubles would be over. Our profession would be regarded more highly by the public at large; our professional development would increase; our prestige would be enhanced; but most important of all, our general level of remuneration would rise.

The doctor, the lawyer, and the clergyman have a great advantage in respect to recognition and regard by the public because each of these is in close professional contact with the individual, who inevitably in his lifetime must become a client of all three, and who, as we know too well, will pay handsomely for professional services when his body is sick or his pocketbook is in danger. The average engineer, in this day of highly organized industry, enjoys but little if any professional contact with the individual, who in turn has usually only the vaguest idea of what engineers do in society's scheme of things.

Thus the formation of a national engineering organization is a much to be desired step but is is only the beginning of a long, hard job of attaining the prestige and recognition which the profession deserves of the public. We should be quick to establish and join the association but we also should be prepared to take really active part in it.

O. W. MANZ, JR. (M '34)
(Assistant manager, system operation department, Consolidated Edison Company of New York, Inc., New York, N. Y.)

To the Editor:

I agree wholeheartedly with AIEE President B. D. Hull that an American Engineering Association should be initiated. I believe that an organization of this type would

enhance the position of the engineer in his profession.

At present the engineering associations are in a position analogous to a group of executive vice-presidents, each in charge of a particular phase of the engineering business, and each growing by leaps and bounds yet contained within their orbits. To make this organization more effective, there should be a central group, whose interest is the interest of all the engineering associations but in addition is omnipotent. Such a group, which Mr. Hull calls the American Engineering Association, would have the lobbying powers equivalent to the American Medical Association which has accomplished much for the medical profession.

There yet remains considerable education necessary for the business world so that the stature of the engineer is raised. In many plants, the engineering group is but one step above that of technicians. One duty which a new over-all association must perform is to raise the level of the qualified engineer and to expose pseudo-engineers. The central association should have the backing of all engineering associations in advancing legislation where required for the advancement or the protection of the engineers.

A. WISE (A '48)
(Associate engineer, Brookhaven National Laboratory, Upton, N. Y.)

To the Editor:

President B. D. Hull's article, "Organization of an American Engineering Association," brings me to ask some questions and also to bare my confusion in evaluating the thinking that is being done on the subject.

I know nothing about organizing a movement of this kind and have deep respect for those who do although I might not agree wholly with their aims and methods. The need for unified action by our Founder Societies long has been felt but never so much as in recent years when collective bargaining has threatened our professional status. With that threat came a dark horse, the National Society of Professional Engineers to do something about it. They put a representative in Washington to watch over our interests in legislation and salvaged us from labor union domination in the Wagner Act. The NSPE is in position to represent all engineers because it is composed of only men who are engineers under the various state laws. The Founder Societies cannot make that boast. Nobody seems to know how many Founder Society members are registered engineers. No guess that I have heard has been as high as 50 per cent. What influence can an American Engineering Society have with the Labor Relations Board when less than half of the members legally can call themselves engineers?

The NSPE has members associated locally in a strong society. A simple line of representation is established through state societies. The individual is the basic unit. A set of uniform grades and qualifications has been adopted regardless of the technical branch to which the individual belongs.

It seems that our Founder Societies are being goaded into action by NSPE that already has accomplished much that we should have done long ago. It looks pompous of us now to look down our Founder noses at NSPE and propose a parallel movement that must make beginning mistakes or benefit from the history of a society that we scorn. It might be a difficult selling job to persuade NSPE that they should transfer their work to any American Engineering Association in a deal whereby they furnish the capital and we the need. Why not recognize them for the progress they have made on our social, economic, and professional problems and keep AIEE in the traditional technical field?

E. E. KIMBERLY (M '41)
(The Ohio State University, Columbus, Ohio)

To the Editor:

The advocacy of a super association of engineers, as in the article by President B. D. Hull published in the April issue, following various previous statements from high authority, also favorable, leaves some of us with an impression that only one side of the case has been presented. No one likes to take issue with men of such standing as have advocated the formation of the American Engineering Association, but I for one do not like either to see anything as important as this go through without full consideration of all aspects, including the adverse. In publishing Mr. Hull's address you invited comments. I therefore submit the following in opposition.

In the report of the subcommittee on professional activities, published in *ELECTRICAL ENGINEERING* for May 1947, is the following statement:

> The [American Engineering] Association's principal objectives, briefly stated, should be the maintenance of high professional standards among its members, the advancement of standards of engineering education, the enhancement of professional recognition and status, and the stimulation of engineers to take their proper place—individually and collectively—in public affairs.

Of the four objectives stated, the first three are designed to do on a professional plane what any trade union undertakes to do for its members. That is, in plain English, the association will bar those who cannot qualify technically, increase the difficulty of earning an engineering degree, and, as the only interpretation I can make of such words as "enhancement of professional recognition and status," will try to make us all still more conscious of our alleged superiority over the rest of mankind. Sounds rather stuffed-shirty to me.

In Mr. Hull's article he spoke of several specific things the American Engineering Association might do, under the heading of "professional development." These included collective bargaining with employers and the placing of engineers on a par with doctors and dentists when it comes to commissions in the United States Army. Mr. Hull refers only vaguely to the "responsibility of the engineering profession to society" and offers no specifications. Neither did the subcommittee on professional activities. It is significant that both Mr. Hull and the subcommittee list obligations to society *after* the welfare of engineers.

Trying to read some practical application into the euphonious words used to describe the purposes of the American Engineering Association, it appears that one of its principal objectives is bigger incomes for engineers. We have been intrigued with those neat little tables showing average annual incomes of doctors, lawyers, and other professional men, with engineers always at the bottom. There can be no quarrel with any man who thinks his services are worth more and tries to increase his income. But in talking about it, let us use simple English words to express just what we mean. And, if we are concerned over the relatively low pay of engineers, let us not try to conceal it with talk about our responsibility to society which is something difficult to measure in dollars.

Doctors, said to be the highest paid among professional men, deal with human life, suffering, and disease in all walks of life. Lawyers, still better paid than engineers, work with human misfortune, errors, and weaknesses. Neither doctors nor lawyers have been satisfied with rendering services to assist their fellowmen, but have organized to insure that they themselves are well paid. I for one hope that engineers as a group never follow suit. Our shield will be brighter if we hold to the principle that our first obligation is to do a good job for the benefit of humanity and leave all efforts to secure better pay for secondary consideration and for individual action.

It is a tribute to your sense of editorial balance that in the same issue with Mr. Hull's address on this subject you ran the article on political liberty by R. W. King. All those concerned with setting up the American Engineering Association would do well to read and ponder Mr. King's words. Every move to promote restrictive registration of engineers, to "advance the standards of engineering education," or to set ourselves apart from the rest of mankind in an organization with limited membership, is a blow a human liberty. Instead of hoarding engineering ability we should be lavish in expending it. Instead of trying to keep out those we consider inferior, we might better organize to seek out young men in coal mines and on farms who have promise of becoming good engineer material and help them to qualify, with or without degrees. We should disseminate familiarity with engineering methods and techniques. Rather than to seek compulsory registration at one level, excluding all intermediates and apprentices, we might better leave the field wide open to all, distinguishing only those who demonstrate superiority by some honorary procedure unrelated to scholastic attainment or membership in any organization.

Incidentally, there may be a valid reason for requiring registration of engineers who are responsible for structures. This is purely a safety consideration, based upon the police power of the state, and has nothing to do with engineers not concerned with structures. But, to show how ridiculous such licensing measures can become, note that we require registration of a man who puts up even a small structure but allow to go scot free the physicists and engineers who are making atomic bombs.

As a final point, the advocates of the American Engineering Association should review occasionally the history of modern engineering as related to social development. It was the mechanical engineer with his steam engine and later his internal combustion engine who accelerated the industrial revolution with its associated inversion of our farm-and-city population ratio. As technology has grown, our liberties have declined. Life in cities is more and more highly organized and regimented with every new invention. Look at the helpless masses of humanity in the New York subways at six o'clock every evening. Moreover, the engineer has bult the mechanisms of war. Is it not about time

he began to realize that if there is to be a stop to the wasting away of our liberty, he himself must give some thought to it? He has contributed mightily to bringing us to our present state. Instead of worrying about his professional development in order to forge still more chains for a once-free people, he should devote some time and effort to see that his works are better applied for the benefit of his fellowmen. An organization for that purpose would have my heartiest support.

CHARLES H. ROE (M '36)
(68 Lake Avenue, Tarrytown, N. Y.)

To the Editor:

I would like to congratulate AIEE President B. D. Hull for his fine article on "An American Engineering Association," in the April issue of *ELECTRICAL ENGINEERING*.

It is high time that the engineers began thinking of forming a united group that will include all the branches of engineering. Look at the American Medical Association—the power, prestige, and benefits the doctors enjoy, thanks to their united effort to represent themselves as one solid block.

In Europe, and in Greece in particular, the engineer is regarded as more important, is paid more than a member of any other profession, and is highly respected by the community.

Pause and think for a moment. Take a look at the daily life of your community, the nation, and the world in general, and ask yourselves the following questions.

Who won the war? Who is going to win the peace? Who is behind production? Who will combat diseases by improving sanitary conditions? Who is going to aid the doctor to conquer cancer? And lastly, who holds the destiny of the world at the crossroads between construction or destruction? Naturally you all will say the engineer. Yes, the engineer has a great potential power and he is aware of it, but he lacks the ability to sell himself to the public and to his employer. Many common laborers earn more than an average engineer; are not you curious enough to ask yourselves why?

You spent years and years to prepare and ready yourselves day and night to be useful to your community and to your country. Why cannot you put aside a few hours once a month, or once a year, and lay the gound work, and build a magnificent building—that of the "united American engineer?"

Unification is possible because it is for the benefit and advancement socially as well as scientifically of all individuals concerned. Let us all say "forward" with this splendid idea of AEA. Think about it, talk to your associates, write to your publications. Do not stand like a mere spectator, do something concrete about it.

Last year, Dean Feiker and Colonel N. B. Ames, who are still very interested in the unification of engineers, had a special meeting with the best speakers available to push that ideal further. The attendance was not great, but the spirit and the co-operation on the part of the audience was splendid.

If a group of few men, say a dozen or more, representing the various societies, and financed by their respective treasurers, will devote 6 to 12 months full time directing their energies, efforts, influences, and everything they got in one channel—that of unification—this dream will become a reality before 1950.

JOHN E. PARASKEVAS
(Bliss Electrical School, Washington, D. C.)

Voltage Notation Conventions

To the Editor:

The much-maligned "butterfly (vector) diagram" for the 2-winding transformer mentioned in these columns with regard to "Voltage Notation Conventions" (*EE, Jan '48, pp 41–8*) deserves a kinder fate. Whenever arbitrary conventions and proposed standards introduce confusion by masking fundamental concepts and baisc principles, then those proposals should be subjected to critical reexamination.

Specifically, the authors' application of convention IIA in Appendix I to a 2-winding transformer results in a vector diagram showing the primary and secondary voltages in phase, except for the small effects due to the usual leakage impedance drops. Several objections, embodying basic principles and experimental facts, should be mentioned in examination of this analysis.

Without regard to any arbitrary assumptions concerning current directions or subscript notation, the voltage of magnetic induction only can be expressed by the fundamental relation

$$e_L = -\frac{d\lambda}{dt} = -\frac{d}{dt}(N\Phi)$$

This conforms with equation 16 of Appendix I, but is at variance with equation 15. It should be emphasized that the minus sign is as much a part of this basic statement of experimental fact as any of the other factors, and as such is simply a direct consequence of restrictions imposed by the conservation of energy. A moment's thought should reveal the necessity for this requirement, since without the minus sign, the slightest increase in flux linkages—fortuitous or otherwise—would give rise to an increment of voltage which would bring about a further increase in flux linkages, with a clearly absurd final result. Perhaps it would be helpful to point out that there is a sign associated with the time rate of change of the quantity in the equation for the induced electromotive force; that is, the induced electromotive force always must act within the circuit to oppose any change taking place. If conventions of convenience are to be introduced, they should not detract from this basic experimental fact, and the arbitrary nature of any assumptions so made must be stressed repeatedly.

By virtue of the afore-mentioned fundamental concept of Faraday and Henry, it follows that for a sinusoidal time variation of flux, the vector representing the induced electromotive force only can be drawn 90 electrical degrees behind the flux vector. As the analysis under review specifies the two windings to be wound in the same sense, it follows that the induced electromotive forces in these two windings clearly must be in time phase. The vector $\boldsymbol{I}_e$ (Figure 7 of Appendix I) can be used as an approximate reference for the flux vector, so that these two collinear vector electromotive forces can be shown 90 degrees behind this current. The subsequent development then results in the two terminal voltage vectors being shown approximately 180 degrees apart in time, rather than nearly in phase. The resultant "butterfly" diagram then becomes an extremely helpful mnemonic representation for analyzing transformer action. It is true that the distinction between voltage drops and rises must be maintained, but frequently in the analysis of machinery performance (d-c as well as a-c) these concepts are almost indispensable for clarity of thought, and certainly are of great value for concise and logical reasoning. Thus, the butterfly diagram depicts the primary current associated with a voltage drop, thereby representing power absorbed. This power must be accounted for, and through transformer action appears as a current associated with the voltage rise in the secondary. Admittedly, the equivalent circuit representation is also a useful convenience, but emphasis should be placed on the fact that this circuit is physically fictitious for obvious reasons. Thus, it does not follow that there shuld be complete correspondence between the two methods of attack.

Another result of convention IIA as applied in Appendix I, concerns the phase relation between the currents $\boldsymbol{I}_{aa'}$ and $\boldsymbol{I}_{b'b}$. Frequently in analyzing transformer action, it is helpful to apply the criterion that the magnetomotive forces of primary and secondary must balance out to zero for an ideal unit. This equality of magnetomotive forces is, of course, a consequence of conservation of energy, and its application to certain transformer topics permits a clear and concise explanation. The vector diagram of Figure 7 of the article scarcely would indicate that in the case of an ideal unit the two magnetomotive forces neutralize completely; or that in an actual transformer the vector sum of primary and secondary magnetomotive forces must equal the exciting magnetomotive force.

In the discussion dealing with voltage direction versus voltage polarity, the proposal to ignore the distinction between voltage drops and rises, scarcely seems tenable. Certainly an important aspect in the analysis of circuits and machinery involves the identification of sources of power, and "sinks" of power, or loads. One of the simplest methods of physical recognition of these two possibilities, is that of noting whether the current is associated with a voltage rise or drop. The argument that an oscillograph records only polarity, without further specification of source or "sink," merely indicates the limitation and incompleteness of that type of measurement.

HENRY B. HANSTEEN (M '43)
(Professor of electrical engineering, Cornell University, Ithaca, N. Y.)

English Teachers for Engineers

To the Editor:

The provocative and ably written article on "Training English Teachers for Engineers," by W. George Crouch and Robert L. Zetler (*EE, Dec '47, pp 1182–4*), was called to my attention by one of our engineering students in freshman English.

I agree with some of the authors' statements about the frequent failure of our

English courses to do much for the engineering students, but I disagree with one or two of their main assumptions and suggested remedies.

In the first place, I believe it is a fallacy to speak of "engineering English" as though it is a language apart. Engineers use the same language, the same sentence structure, the same methods of organizing their ideas as anyone else who writes a report, a letter, or an article. A glance at the excellent articles in your magazine confirms this truth. The fact that technical terms and engineering ideas are employed does not modify it. The engineer who expresses himself well in his reports also can express himself well in a political speech, and conversely.

One does not alter what has to be taught by calling freshman English for engineers "engineering communications," which, incidentally, suggests to the mind all kinds of extraneous things, like radio or television or transoceanic telegraphy. "Communications" as applied to English courses represents a new jargon, and anyone well trained in English knows what jargon is. For good writing the discipline is English composition—it always was and it always will be.

Mr. Crouch and Mr. Zetler tell us that "an English department is concerned primarily with aesthetics." I am not sure I know what they mean, but, if they mean what I suppose they do, they are repeating a fallacy that often is expressed by engineers, lawyers, and chemists, but that would be denied emphatically by the great majority of English professors. All the required freshman English courses that I ever have had to do with and that I ever have heard about, with the occasional exception of courses in purely liberal arts institutions where there are no engineering students anyway, have quite another primary aim. This aim is to give instruction in the writing of clear, accurate, logical expository English prose. The ability to write this is what every educated American needs, be he farmer, pharmacist, or engineer. And the ability is the same, whatever the profession.

The authors tell us that engineers do not always acquire this ability from their present courses. Very true. And neither do many of their fellow students in premedicine or business administration or liberal arts. But the cause is much deeper than the kind of training being given our graduate students in English. It goes back to our whole educational system, to what society demands of its schools, to the entire cultural fabric of society itself. Some college instructors are poor teachers, to be sure. But neither college English instructors nor their training can be handed the larger part of the blame for the poor command of English shown by so many of our graduates. Actually they are more keenly aware of the situation and are working more desperately to improve it than any other group of educators or professional men.

I have taught engineers in my freshman classes for the last 13 years. By and large they have been responsive, interested students. My experience has been decidedly different from that of the authors of the article, for I have found that a majority of engineering students *do* learn English. They are generally serious young men, preparing for a profession they are rightly proud of, and recognizing the great importance of acquiring skill in expository writing. English instructors can help them attain it, and only a misunderstanding of what English is can lead one to demand an engineering training of these instructors.

A. LAURENCE MUIR
(Associate professor and chairman of freshman English, University of Arizona, Tucson, Ariz.)

The Heat Pump

To the Editor:

It has been some time since I have had an opportunity to write regarding the excellent presentation of articles in the recent issues of *ELECTRICAL ENGINEERING.* I am a constant reader and particularly enjoyed the series of articles on atomic energy and related subjects.

Occasionally there are articles of particular interest in the field of electric heating which are valuable in most instances. In your April issue there is a fine presentation on the heat pump (*EE, Apr '48, pp 338–48*), a subject that my company has followed with interest for more than 15 years. I think the discussions are admirable and express the views of most utility engineers today. At the same time I am conscious that utility engineers are inclined to be more favorable toward the heat pump than the facts seem to justify.

My personal experience has been similar to that reported by W. E. Johnson of the General Electric Company in an article titled "Practical Aspects of the Heat Pump," in the April 1948 issue of *Architectural Record.* Briefly, the heat pump has many arguments in its favor but at the present time appears to be impractical for domestic use.

In the section of the symposium on the heat pump by S. W. Andrews, there is the frequently made statement that the annual load factor of resistance heating load is very poor, varying from 10 to 20 per cent in different parts of the United States. He goes on to state that for this reason electric house heating by space heaters is not likely to be widely attractive to customers, because the customer probably always will have to pay a premium for this electrical service. The implication is that the heat pump has a better load factor and is therefore more attractive to utilities. I would like to challenge this statement, based on the recent studies that the AIEE published and were made by the Portland General Electric Company (AIEE miscellaneous paper 48–95, "Electric House-Heating Tests in Oregon," W. L. Sharp, A. E. Opdenweyer).

In this report it is shown that the annual load factor of resistance heating at the time of system peak is 30 per cent, and, though we know that the load factor will vary for different parts of the country, we also know that the annual load factor for resistance heating can be as high as 40 per cent in many areas of the United States.

Our studies show that the heat pump contributes no improvement to the load factor or to the system peak of the utility, except in limited areas where there is a balanced requirement for heating and cooling. For example, in the Seattle, Wash. area, where the heat pump has been highly publicized, there actually would be a reduction in the annual load factor if heat pumps were substituted for unit-type resistance space heaters. This readily can be shown from the test data cited in the foregoing, as there is no cooling requirement in Seattle and as the heat pump is a central heating system that has a less desirable load factor than unit-type heaters.

I am inclined to think that many utility engineers lose sight of the fact that there are only a few domestic heat pump installations in the entire nation, counted in the hundreds; whereas, there are many thousands of resistance-type electric space heating systems, 30,000 on the West Coast alone. We have found that the public prefers to make a small down payment on its heating plant and continue to make payments at various periods throughout the life of the house, rather than make a heavy initial investment to reduce the fuel costs that are spread over a long period of time.

Resistance-type heating has many advantages over the heat pump, and most of these advantages are overlooked by utility people who justly are concerned about the load factor problems. This is to say that the public prefers resistance-type heating because of its small initial cost, lack of any maintenance required, minimum space requirements, and other home convenience assets that will make it necessary for the utilities to serve resistance heating load even though they might prefer some other load. We recognize, of course, that the utility justly can ask that electric resistance heating be a profitable load to the utility.

There are many opinions as to what is profitable as to load, and, briefly, our feeling is that an electric space heating load must be considered as a part of a total load rather than stand alone. This is because it seems unreasonable to ever have to expect a utility to supply service to a given customer for electric space heating only, which is commonly the case with other fuels such as gas, oil, and coal.

Undoubtedly, the heat pump will be advantageous to some users and utilities in limited areas of the country, but generally it can be shown from weather maps of the United States that resistance heating has a much brighter future.

In the section of the symposium on "Engine Drives," by K. W. Miller and N. C. Penfold, there is a very sound argument that seems to have considerable merit. Carrying this discussion one step further, we have found that it is entirely practical to produce a low-compression low-speed single-cyclinder-type engine that will generate sufficient heat and electric energy to meet the requirements of a domestic unit. This machine can be manufactured and installed in thinly populated areas at less expense than by running distribution lines. In addition, less maintenance is required, particularly where line maintenance is an extremely difficult problem during bad weather conditions. Such an engine has a maximum efficiency of 87 per cent, with less investment and operating expense than any heat pump design. The fuel can be liquefied petroleum gas, natural gas, or oil.

It is very satisfying to us that there has been an increase in interest in space heating. We feel that, with more articles like those in the April issue of *ELECTRICAL ENGINEERING* and more discussions at the AIEE meetings, the electric heating industry unquestionably will benefit. I think perhaps the heat pump and radiant panel heating have received more publicity than the facts would justify. Radiant heating particularly has been talked about in such glowing, generalized terms that many home owners have

been disappointed because their heating engineer failed to recognize the limitations of this type of heating in their particular climate area. For example, radiant heating has been rather unsuccessful on the West Coast.

My present problem in the industry is a combined program to educate utility people as a whole as to the true position of electric heating systems, and at the same time to improve those systems in certain areas that have a less favorable load factor. It appears from experience gained thus far that no one solution will answer the problems of all the utilities, as the conditions vary depending upon local climate, local energy source, and types of local industry.

J. C. BECKETT (A '40)
(Chief engineer, Wesix Electric Heater Company, San Francisco, Calif.)

NEW BOOKS • • • • •

"FM Transmission and Reception." This book covers the principles underlying the operation of frequency modulation transmitters and receivers. The treatment is essentially nonmathematical. Narrow-band and wide-band transmitters used in television, amateur radio, aviation, marine work, point-to-point installations, and mobile radio systems are described in the first part of the book. Both direct and indirect frequency modulation theory is explained. Transmitting and receiving antennas also are covered. The second section of the book covers the frequency modulation receiver, comparing each stage of the receiver with its counterpart in an amplitude-modulation-type receiver. Detectors, tuners, alignment of frequency modulation receivers, and servicing problems are treated in some detail. A bibliography and index also are included. By John F. Rider and Seymour D. Uslan. John F. Rider Publisher, Inc., New York, N. Y., 1948, 409 pages, $5^1/_2$ by $8^1/_4$ inches, paper-bound—\$1.80, cloth-bound—\$2.70.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ELEMENTARY MECHANICAL VIBRATIONS. By A. H. Church. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 200 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3.25. Based upon courses given at New York University, this book covers the elementary principles and serves as an introduction to more extensive study of vibration problems. The author stresses the physical rather than the mathematical explanations of the phenomena. One chapter is devoted to balancing. A knowledge of mechanics and calculus is assumed. Extensive use of examples clarifies the text, and problems, with answers, are given at the end of each chapter.

ELEMENTS OF NOMOGRAPHY. By R. D. Douglass and D. P. Adams. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 209 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3.50. This book deals with the study, understanding, creation, and practical use of the alignment chart. Seven elementary types are presented, including the circular nomograph. Practical aids to hasten and simplify the completion of the theoretical solution and the drafting of the chart are developed. Among these are the systematic adjustment of the scale measurements to the base line of the diagram, the regular use of prepared forms, and the practice of checking solutions. Compound alignment diagrams are dealt with in the final section.

INSTRUMENT AND CONTROL MANUAL FOR OPERATING ENGINEERS. By E. W. F. Feller. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 426 pages, illustrations, diagrams, charts, tables, $8^1/_4$ by $5^1/_4$ inches, cloth, \$6. This book is a practical manual of information used for the quick and sound solution of specific metering and control problems. It explains the basic principles of control and describes the construction and operation of liquid-level, pressure, temperature, speed, and humidity indicators and controllers. After individual units are detailed, the complete operation is inspected. Numerous diagrams and charts illustrate the text, and a glossary of terms is included.

INTRODUCTION TO ELECTRICAL ENGINEERING. By G. V. Mueller. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1948. 591 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$5. As in previous editions, this volume discusses electric, magnetic, and dielectric circuits under transient and steady state conditions. Considerable revision and enlargement have been made to include such topics as ohmmeters, heating and cooling curves, and node-pair voltages. Treated now are the superposition and Thevenin's theorems. Potentionmeters, thermocouples, grounding, rectifier instruments, design of permanent magnets, and the inductance and capacitance of transmission lines also are considered in the new edition.

INTRODUCTION TO MODERN PHYSICS. By F. K. Richtmyer and E. H. Kennard. Fourth edition. McGraw-Hill Book Company, New York, N. Y.; and London, England, 1947. 759 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$6. Following a historical sketch covering the period from antiquity to 1890, this standard text discusses the basic electromagnetic, photoelectric, and thermionic concepts. Succeeding chapters deal at some length with the sucessively developed theories of the modern era. In this new edition, changes have been made to include the significant advances of the past five years. Extensive additions have been made in the discussions of nuclear energy and cosmic rays, and quantum states rather than wave functions now are used in the explanation of the theory of many electron atoms.

NOMOGRAPHY. By A. S. Levens. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 176 pages, diagrams, charts, tables, $9^1/_4$ by $5^3/_4$ inches, cloth, \$3. Of interest to the scientist and practicing engineer, this book presents fundamental principles of the design and theory of an important graphical method. Emphasis is placed on the geometric method of development, and after the theory is explained, short cuts are described. A knowledge of algebra, plane geometry, and logarithms is assumed. One chapter is devoted to the use of determinants in alignment chart work. Practical examples of charts and a selected bibliography are included.

PRINCIPLES OF INDUSTRIAL MANAGEMENT. By E. A. Allcut. Fourth edition. Sir Isaac Pitman and Sons, Toronto, Ontario, Canada, 1947. 308 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$4. Intended for use by students as a text, this volume does not attempt to describe the details of industrial administration. After a discussion of the general principles of management, the specific topics of organization, reports, purchasing, budgets, planning, work routing, and stockroom procedures are treated. A chapter on time and motion study is ihcluded, as well as chapters on inspection, costs and cost keeping, industrial labor relations, and waste.

PROBLÈMES D'ÉLECTROTECHNIQUE A L'USAGE DES INGÉNIEURS. By A. Fouillé, preface by P. Boucherot. Second edition. Dunod, Paris, France, (6e), 1948. 291 pages, diagrams, charts, tables, $9^3/_4$ by $6^1/_2$ inches, paper, 680 frs. This book presents a wide variety of problems beginning with the simpler aspects of electricity and magnetism and continuing on through the transmission and distribution of electric energy. Each section contains sample problems worked out in detail followed by examples to be worked by the reader. Both a-c and d-c circuits and equipment are coverd including capacitors and transformers.

RADAR AIDS TO NAVIGATION. Edited by J. S. Hall. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 389 pages, illustrations, diagrams, charts, maps, tables, $9^1/_4$ by 6 inches, cloth, \$5. This book describes the present advantages and limitations of radar equipment when applied to problems in navigation and pilotage. Air-borne, ship-borne and ground-based systems are discussed, as well as radar beacons and other auxiliary equipment. Radar indicators are described in detail. Descriptions of various nonradar navigational aids also are included. Although this volume is technical in nature, four chapters are so designed as to provide a fair estimate of the value of radar in navigation for the reader with no technical background.

PAMPHLETS • • •

Some Basic Techniques in Materials Handling. A report of the proceedings at technical sessions of the Conference on Materials Handling, in Cleveland, Ohio. The book is believed to be the first report of its nature ever published and one of the few texts on materials handling problems. Nineteen papers are included. The book contains 84 pages, $8^1/_2$ by 11, is paper-covered, and includes 15 pictures, 11 diagrams, and 4 charts and tables. It may be obtained for \$1 from Clapp and Poliak, 350 Fifth Avenue, New York 1, N. Y.

New Products. A booklet compiled by the New York *Journal of Commerce.* More than 750 different concerns are listed in this compilation, along with a detailed description of the new products they are about to introduce. Copies of this 1948 edition of "New Products" may be had at 50 cents each from the New York *Journal of Commerce*, 63 Park Row, New York, N. Y.

Printed Circuit Techniques. The National Bureau of Standards has published a comprehensive treatment of the subject of printing electronic circuits entitled "Printed Circuit Techniques," by Doctors Cledo Brunetti and R. W. Curtis. The booklet consists of 10 chapters totalling 43 pages and is illustrated with 21 half tones, 18 line cuts, and 5 tables. NBS Circular 468, "Printed Circuit Techniques," is now available from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C., at 25 cents per copy.

Experience in Illinois With Joints in Concrete Pavements. Investigations conducted by a special committee composed of members of the staffs of the departments of civil engineering and theoretical and applied mechanics of the University of Illinois college of engineering and the Division of Highways, State of Illinois. The bulletin contains 62 tables and 134 figures. Bulletin 365, "Experience in Illinois with Joints in Concrete Pavements," by J. S. Crandell, V. L. Glover, W. C. Huntington, J. D. Lindsay, F. E. Richart, and C. C. Wiley. Issued by the Engineering Experiment station, University of Illinois. Copies of the publication will be mailed free on request for a limited period from the Engineering Experiment Station, University of Illinois, Urbana, Ill.


KERITE

INDUSTRIAL NOTES ....

Lamp Factory. The lamp department of the General Electric Company, Cleveland, Ohio, announces that it will begin construction of a factory in Champaign, Ill. The new plant, which will cost approximately $1,200,000, will be located on a factory site of about ten acres just outside the Champaign city limits on North Market Street. The proposed factory will be a one-story building about 50,000 square feet in area.

New Address. The executive and general offices of the Independent Pneumatic Tool Company, previously located at 600 West Jackson Boulevard, Chicago, Ill., will transfer to the company's new administration building adjacent to the main works at Aurora, Ill.

Utility Expansion. More than $665,076,000 will have been invested since the war in new plants and equipment in Pennsylvania by public utility companies it was shown in an industrial survey announced in Harrisburg, Pa., by Governor James H. Duff and Secretary of Commerce Otus J. Matthews. A total of 49 public utility companies reported. This is part of an expansion of more than two billion dollars reported by 1,086 companies which had participated in an industrial survey conducted by the Department of Commerce of the Commonwealth of Pennsylvania. The survey contained figures on construction for 1946 and 1947, and estimates for 1948.

Purchase. Western Electric Company has arranged to purchase a 130-acre industrial site for the construction of a manufacturing plant at Indianapolis, Ind. The new plant will be designed specifically for the production of telephone sets and associated equipment presently being manufactured in leased quarters principally in the Chicago area. Construction of the new plant will begin within the next few months to permit occupancy during 1950.

Island Equipment Corporation to Move. Island Equipment Corporation with general offices located at 101 Park Avenue, New York 17, N. Y., and factories at Hollis and Queens Village, N. Y., has negotiated for new and larger quarters in which the general offices and factories will be consolidated, all under one roof. The new plant will be that modern structure formerly occupied by Brewster-Rolls Royce organization at 27-01 Bridge Plaza North, Long Island City 1, N. Y.

Westinghouse 1947 Output. Net income in 1947 for Westinghouse Electric Corporation, Pittsburgh, Pa. amounted to $48,806,417 equal to a fraction less than seven per cent return on total sales. Net income, after provision for preferred stock dividends, was equal to $3.58 per share of common stock outstanding. This compares with net income of $8,823,846 or 65 cents per share of common stock outstanding in 1946, a year in which operations were affected adversely by a 4-month strike. New orders received in 1947 amounted to $849,930,945 compared with $624,672,985 in 1946. At the end of 1947 the backlog of unfilled orders totaled $685,340,339 compared with $589,583,459 in 1946.

Air Associates. Doctor K. C. Black has joined the staff of Air Associates, Inc., Teterboro, N. J., in the capacity of chief radio engineer.

New Sales Executive. Morningstar, Nicol, Inc. announces the consolidation of its industrial adhesive manufacturing subsidiaries, Paisley Products, Inc., of Illinois, and Paisley Products, Inc., of New York. Murray Stempel, formerly general manager of the Chicago company, has been elected vice-president and general manager of the consolidated operations. Earl C. Lenz, formerly sales and service manager of the Chicago plant, has been promoted to general sales manager. He also will continue to direct the advertising and sales promotional activities of the consolidated operations. L. J. LaBrie, formerly technical director, has assumed the position of sales manager of the New York plant.

Television Sets Sent to 21 States During 1947. A total of 162,181 television receivers was shipped to 21 states and the District of Columbia during 1947, the Radio Manufacturers Association revealed recently. Actual shipments of television sets during 1947 fell below the approximately 178,500 receivers manufactured, the RMA report pointed out, the difference being accounted for largely by television sets held in factory inventories at the end of the year. During the first quarter of this year, 118,027 television sets were manufactured by RMA member-companies, bringing the total production since the war to more than 300,000 as of April 1. Only 6,476 television sets were made in 1946.

Vagtborg Resignation. Doctor Harold Vagtborg, president and director of Midwest Research Institute at Kansas City, Mo., has resigned to permit him to accept appointment, effective September 1, 1948, as president and director of Southwest Research Institute based in Houston, Tex.; as director of the Institute of Inventive Research; and as director of the Foundation of Applied Research; also as technical director of the 3,500-acre

(Continued on page 32A)

ANOTHER Good Reason for using Square D Control

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All motor starters and contactors are subject to periodic contact replacement under conditions of heavy load or frequent operation. That's why Square D has always stressed accessibility of these parts. Now, the parts themselves are packaged in easy-to-stock kits to make that replacement job even more simple.

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(*Continued from page 14A*)

INDUSTRIAL NOTES

Essar Ranch, all located just outside the city limits of San Antonio, Tex.

Leeds and Northrup Engineer Retires. Paul V. Roth, shop engineer of Leeds and Northrup Company, Philadelphia, Pa., recently retired after 46 years of service with the company.

Lightning Losses. Thirty seven per cent of all rural losses are due to lightning. This is a fact developed by the National Board of Fire Underwriters research records, for the past four years. The National Board of Fire Underwriters is an independent organization. Each year in the United States, approximately 1,500 persons are killed or injured. Statistics show that eight per cent of lightning losses occur in rural communities of 3,500 or fewer.

Assistant Director. Edgar A. Jett, II, has been named assistant director of Armour Research Foundation of Illinois, Institute of Technology.

Crocker-Wheeler Boston Manager. C. Porter Packard, Canton, Mass., has been appointed district manager of the Boston office territory of the Crocker-Wheeler Electric Manufacturing Company, division of Joshua Hendy Corporation, it recently was announced from the company's main offices.

Consolidation. I-T-E Circuit Breaker Company, and its subsidiary, Railway and Industrial Engineering Company, announce the consolidation of their sales offices and the opening of a district sales office at 74 Trinity Place, New York 6, N. Y.

RCA Appointment. J. A. Milling has been appointed to the newly-created position of commercial vice-president of the RCA Service Company. Prior to his appointment, Mr. Milling was general manager of the parts division of the RCA tube department.

Coogan Joins Dolph Company. Walter A. Coogan, for the past 15 years director of the international division, Sylvania Electric Products, Inc., has resigned this position to join the John C. Dolph Company, Newark 2, N. J., as executive vice-president and director.

Allen-Bradley Moves. New and larger quarters have been acquired for the Detroit office of the Allen-Bradley Company, Milwaukee, Wis. The new quarters are at 11100 East Warren Avenue, Detroit, Mich.

(*Continued on page 34A*)

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Small sizes or large . . . one, two or three conductors . . . moisture-resisting insulation . . . from 0 to 5,000 volts . . . Durasheath is built for rugged service:

Durasheath offers high tensile strength and resistance to impact and abrasion—*plus* extreme flexibility that makes it easier to handle. Also, Durasheath resists moisture, acids and alkalies generally found in the soil, eliminates problems of electrolysis, corrosion and extremes in temperature and is highly resistant to flame—making it possible to use a single type and size of cable in runs that are partly aerial, partly underground or in conduit.

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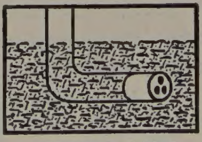

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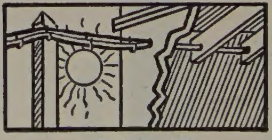

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Anacondaloy*-coated copper conductors are insulated with a moisture-resisting synthetic rubber compound, bound with color-coded rubber-filled tape and enclosed in a tough, high mechanical strength, moisture and flame-resistant outer jacket of Neoprene. Conductors have the lasting protection of a solid block of synthetic rubber and Neoprene.

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(Continued from page 32A)

TRADE LITERATURE

Connector Selector. A quick-reference novelty catalogue, "Connector Selector," is available from Burndy Engineering Company, Inc., New York 54, N. Y. This booklet also can be used as a compact, convenient wall chart. Because the variety of conditions encountered in making electric connections are so numerous, the Burndy "Connector Selector" is offered to simplify the choice of the right connector for every job. Terminals, taps, T-connectors, and splices are indexed for fast selection, and complete ordering information is given for every connector.

NEW PRODUCTS • •

Intensity Meter. A new portable field intensity meter, the smallest and lightest unit of this type yet developed, was introduced recently by the RCA engineering products department at the annual convention of the National Association of Broadcasters at Los Angeles, Calif. The meter (RCA type *WX-2A*) weighs approximately $12^1/_2$ pounds (with batteries) and is 12 by $8^1/_2$ by $5^1/_2$ inches in size. It provides direct readings, making it unnecessary to use correction factors or charts, or make computations of any kind. Deliveries of the new meter will start in July. The current price of the unit is $575. RCA Victor Division, Camden, N. J.

Miniature Tube. Two new miniature electronic tubes, types *6AV6* and *12AV6*, have been made available by the tube department of General Electric Company's electronics department at Schenectady, N. Y. Providing a mu of 100, they are designed for use as combined diode-detectors, automatic-volume-control tubes, and first audio-frequency amplifiers.

Rotary Solenoid. Two new Ledex rotary solenoids (patents pending) have been developed which produce torques of 25 and 50 pound-inches, respectively. The Ledex number 7 is $2^3/_4$ inches in diameter, weighs less than $2^1/_2$ pounds, and produces a starting torque of 25 pound-inches with a 45-degree rotary stroke. The Ledex number 8 rotary solenoid, $3^3/_8$ inches in diameter and weighing slightly more than four pounds, develops a starting torque of 50 pound-inches with a rotary stroke of 45 degrees. A choice of wire sizes from number 13 to number 35 represents d-c operation from 6 to 550 volts. Rectifiers can be supplied, as accessories, for solenoid operation on alternating current. For further information contact G. H. Leland, Inc., 109 Webster Street, Dayton 2, Ohio.

(*Continued from page 34A*)

NEW PRODUCTS

Sensitive Relay. Allied Control Company, 2 East End Avenue, New York 23, N. Y. announces their new type *BK* relay and recommends its use especially under conditions of limited power supply and also where precise operating characteristics are vital. Designed for extra sensitivity, the Allied *BK* relay has molded Bakelite insulating parts throughout, easily accessible contact screws capable of precise adjustment, and standard screw-type terminals. It is supplied in 1-pole or 2-pole, normally open or normally closed contact arrangements, also double throw.

A-C and D-C Time Relays. The A. W. Haydon Company, Waterbury, Conn., announces that a new series 11400 a-c and 6400 d-c time delay relay are available. These relays have planetary differential and "capstan" clutch mechanism which is designed to drive the switch actuating arm when the clutch holds the third element of the differential stationary. Mechanical amplification forces obtained in the "capstan" clutch allows the use of a small electromagnet, thus reducing the operating current and the size of the unit. The "capistan" clutch also resists vibration and shock and assures positive operation under adverse conditions.

Rowe-Type IPS10000 10-kv ISO-Volt D-C Power Supply. The Rowe-type *IPS10000* 10-kv ISO-volt d-c power supply provides a source of continuously variable direct voltage from 1,000 to 10,000 volts at current drains up to 5 milliamperes. Exceptionally high regulation of one-tenth of one per cent is obtained electronically and corrects the output voltage, practically instantaneously, over full line and load variations. Rowe Engineering Corporation, 2422 North Pulaski Road, Chicago 23, Ill.

Stabilized Rectifier. A stabilized rectifier with no moving parts for unattended battery charging that offers new highs in dependability and extended battery life. Voltage regulating transformers compensate for variations in a-c line voltages and maintenance-free selenium rectifiers assure maximum life and efficiency to batteries. Output current of 4-6-12 amperes, output voltage from 3 to 60 cell ratings (booster charging feature included) with the a-c input either 110 or 220 as specified. Manufactured by Industrial Electronics and Transformer Company, Department EE, 1801 East Slauson Avenue, Los Angeles 11, Calif.

Industrial Rectifier Tube. A new, quick heating, 5-ampere mercury vapor rectifier tube has been announced by National Electronics Inc., Geneva, Ill. Known as the *N1-617*, this tube is designed especially for heavy duty industrial rectifier applications at voltages up to 600 volts direct current. Though the *NL-716* is more compact than tubes previously available for this rating, lower condensed mercury temperature is provided which makes possible a peak inverse voltage rating of 1,000 volts. Detailed ratings are: filament volts, 2.0; filament amperes, 12; d-c amperes output, 5.0; peak inverse output, 20; peak inverse volts, 1,000. Complete technical data are available from the manufacturer: National Electronics, Inc., Batavia Avenue, Geneva, Ill.

Dial Instrument. The Marion Electrical Instrument Company has developed a new, rectangular Bakelite-cased model 56 meter. This dial instrument measures $6^1/_2$ by $5^1/_4$ inches. Filling the gap between $4^1/_2$- and 8-inch meters the model 56 has a 100-degree arc, $5^1/_2$-inch scale length and large open face making it easily adaptable to multiarc dials. For further information write to the Marion Electrical Instrument Company, Manchester, N. H.

Electrode for Welding Mild Steel. The Wilson Welder and Metals Company, Inc. has announced the availability of the new Wilson number 109 all-position arc welding electrode for welding of mild steel. This electrode is available in 1/8 inch, 5/32 inch, 3/16 inch, 7/32 inch, 1/4 inch, and 5/16 inch diameters. Further information can be obtained by writing directly to Wilson Welder and Metals Company, Inc., Department 1778P, 60 East 42d Street, New York 17, N. Y.

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